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RANGE MANAGEMENT

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Walter Mulford was Consulting Editor of this series from its inception in 1931 until January 1, 1952.

RANGE MANAGEMENT

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PREFACE

American ranchers, after some hundred years of intensive use of the western range, are only now realizing that there are no new frontiers and that present resources must be made to last us forever. Land misuse and resultant soil erosion will no longer be tolerated by a livestock industry whose future lies undeniably in the soil. Misuse results in decreased production, whereas increased production is the goal of range management. Because of the demand for better management, range research is developing at a rapid rate, stimulated not alone by the scientist but by the rancher himself.

In the twelve years since the appearance of the first edition of *Range Management* there have developed new concepts and new objectives in the science. Much additional information is now available as a result of experience and research upon older concepts and techniques. In line with this progress, the work of revision has necessitated extensive changes. Several sections are entirely new, and others which appeared in the first edition have been much reduced or omitted entirely. These changes were made in the interest of economy and in consequence of changed needs of the profession.

The advice of several associates who have used the book as a classroom text in past years was sought before making the changes. Their suggestions varied greatly, but the present arrangement is believed most nearly to fit the needs for a range-management textbook as expressed by the majority of persons consulted and as revealed by the authors' own experience.

The authors gratefully acknowledge encouragement and suggestions from many colleagues in range management; special gratitude is due the following, who aided through suggesting changes in content and organization and who offered criticisms and suggestions upon portions of the revised manuscript: Dr. H. H. Biswell, Dr. Robert S. Campbell, Dr. C. Wayne Cook, Dr. David F. Costello, Dr. Stanley P. Gessel, Prof. Grant A. Harris, Dr. Harold F. Heady, Dr. Robert R. Humphrey, Dr. R. Merton Love, Prof. Melvin S. Morris, Dr. J. J. Norris. Dr. D. I. Rasmussen, Dr. Joseph H. Robertson, and Dr. Vernon A. Young.

Revision of Chapter 11 on animal nutrition was contributed largely by Dr. Cook.

No less true now than it was at the time of the appearance of the first edition is the statement that range management is a developing science. Future years will supply knowledge which may make our present viewpoints inadequate, perhaps untenable. In attempting an unbiased and complete presentation of present knowledge the authors hope that viewpoints expressed herein will stimulate additional thinking which may result in challenge of questionable practices even though they are at present acceptable. Growth rather than fixity must characterize a useful and vital science of range management.

LAURENCE A. STODDART
ARTHUR D. SMITH

CONTENTS

CHAPTER 1

DEVELOPMENT OF RANGE MANAGEMENT IN THE UNITED STATES

The western United States is predominantly range land and has land-use and economic problems peculiar to it alone. These differ from the problems of eastern states and of most other countries because of certain characteristics that limit production in the West. The most important of these is the low and often poorly distributed precipitation made the more serious because of shallow and unstable soils. The results are sparse vegetation and a landscape marred by erosion.

The limited resources give livelihood to a sparse human population, which derives wealth essentially from minerals, irrigated farming, and grazing livestock supported largely on native vegetation. The supervision and maintenance of the range lands are problems second to none in the West in importance. This is the field of *range management, the science and art of obtaining maximum livestock production from range land consistent with conservation of the land resources.*

It is evident from the definition that range management is closely related to animal husbandry and plant ecology. These sciences and many others are vital to range management.

BEGINNING OF RANGE LIVESTOCK INDUSTRY

Early American history is interspersed with events growing out of the development of the range livestock industry. The Spanish introduced the animals into America, the pioneer Texans cared for them, and there developed a new pattern of living upon which western American life was built.

Original Grazing Animals of the American Continent. A résumé of the conditions existing at the time America was first inhabited is illuminating. No entirely new influence was exerted on the range lands with the coming of domestic livestock, for previously countless numbers of wild mammals grazed the entire continent. Although these animals generally were not so abundant as domestic livestock, it is not unlikely that excessive numbers of the native fauna caused local or perhaps general misuse and overuse of

the range. Over 67 million animal units[1] (Table 1) were believed to be present. This is almost as much as the estimated animal units of livestock using the area today. The white man as a new ecological force merely re-aligned the influences already present and intensified the environmental complex.

TABLE 1. NUMBERS OF BIG-GAME ANIMALS ESTIMATED TO HAVE BEEN PRESENT ORIGINALLY IN THE UNITED STATES

Animal	Numbers*	Number per animal unit (1,000-lb. base)	Animal units
Bison	50,000,000	1.0	50,000,000
White-tailed deer	40,000,000	7.7	5,195,000
Pronghorn antelope	40,000,000	9.6	4,167,000
Elk	10,000,000	1.9	5,263,000
Mule deer	10,000,000	5.8	1,724,000
Black-tailed deer	3,000,000	8.0	375,000
Bighorn sheep	1,500,000	5.6	268,000
Mountain goat	1,000,000	7.0	143,000
Total	155,500,000	...	67,135,000

* Data from Seton (18).

Early Introduction of Livestock into America. The beginnings of the livestock industry in America are associated with exploration and colonization. Columbus is reported to have landed domestic stock, including horses and sheep, in the West Indies in 1493 (1); but it was not until 1515 that Cortes, landing in Mexico, brought livestock to the continent of North America. It is believed that cattle were not included but, rather, that horses only were brought. It is known that cattle were introduced in the year 1521 by Gregario Villalobos (2), who landed them in eastern Mexico. These, however, did not reach the territory of the United States.

De Soto is reported to have brought horses to Florida in 1539 (1); but the first record of the importation of cattle into the territory properly a part of the United States is that of Coronado, who in 1540 traveled from western Mexico northward through Arizona, New Mexico, and Colorado, reaching as far northward and eastward as Kansas (15). Considerable numbers of stock were included, it being reported that 1,000 horses, 500 cows, and 5,000 sheep were taken (20). From these herds, escaped and abandoned animals began stocking the range area. During the next century, considerable numbers of animals were brought to the numerous Spanish settlements established in New Mexico, Texas, Arizona, and California. Finding ample forage and favorable climate, the early stock

[1] An animal unit is considered 1,000 lb. live weight, or roughly equivalent to the weight of a cow and a calf.

increased abundantly, though it was not until many years later that production of range livestock was to become a national industry.

Little can be learned about the quality and kinds of livestock of these early days, but from what is known of the stock in European countries at that time it must be conjectured that these represented a motley array of kinds, shapes, and breeds. Certainly these introductions took place before the development of the improved breeds of today.

Beginnings of Range Livestock Production. When the settlers from the East came to the Mississippi Valley about 1830 and merged with livestock men moving northward from Texas, the range livestock industry can be said to have begun. Broad expanses of grassland gave an impetus to the livestock industry, and though for some years there was a lack of transportation and market facilities, there began a general increase in the western livestock population (Table 2). This was aided by the gradual diminution of the danger from marauding Indians as forts and settlements were built in the wake of trappers and adventurers.

TABLE 2. NUMBER OF LIVESTOCK ON FARMS AS OF JAN. 1 FOR THE 11 WESTERN STATES (26, 27)

Date	Cattle (excluding milk cows) (thousands)	Stock sheep (thousands)	Date	Cattle (excluding milk cows) (thousands)	Stock sheep (thousands)
1867	1,802	5,336	1915	9,577	23,098
1870	2,498	7,214	1920	11,020	21,419
1875	3,661	12,281	1925	9,231	19,814
1880	5,099	16,186	1930	8,096	25,045
1885	7,122	17,366	1935	9,015	24,030
1890	8,421	17,274	1940	8,803	21,602
1895	7,098	19,195	1945	10,246	17,693
1900	7,255	24,803	1950	9,833	11,863
1905	8,968	24,000	1954*	12,474	12,059
1910	7,948	28,228			

* Estimate, U.S. Department of Agriculture, Agricultural Marketing Service.

This growth resulted from nothing but the naturally favorable conditions for livestock. Because of unlimited forage, the animals did well without conscious aid and husbanding by the ranchers.

There were periodic booms, which greatly stimulated the ranching enterprises of the West. The first of these occurred during the Civil War. The need for supplies for Confederate armies provided a ready market for the cattle of Texas. This was only temporary, for the Union blockade soon closed these avenues of commerce. At the close of the war, because of few

cattle in the East and monetary inflation, prices continued high, which stimulated efforts to get animals to market (14). This led to a most interesting stage in the developing livestock industry.

Texas Trail Herds. Though the Texas Longhorn (Fig. 1) had been known on the markets before the Civil War, the number of these cattle was not great. The first account of a northward drive was that of Edward Piper, who, in 1846, took a herd from Texas to Ohio (32). The year 1866 marks the beginning of this movement in considerable proportions.

FIG. 1. A typical Texas Longhorn steer. Note long legs and lack of body depth.

Soldiers returning from the Civil War saw an opportunity to make money by marketing cattle, which had increased remarkably on the ranges, and there was a great rush to this business.

The trails going north from Texas were not single trails but merely a general direction of travel made up of numerous small trails converging at river fords and mountain passes. These trails varied in distance according to the routes followed (Fig. 2).

Movements of livestock often took the form of a series of drives that consumed years, animals leaving Texas as 2- to 4-year-old stock often being sold as 4- to 6-year-olds or more. Similarly, from the northern areas came herds of steers on the way to eastern markets over long and hazardous trails.

These first great movements of livestock were accomplished only with

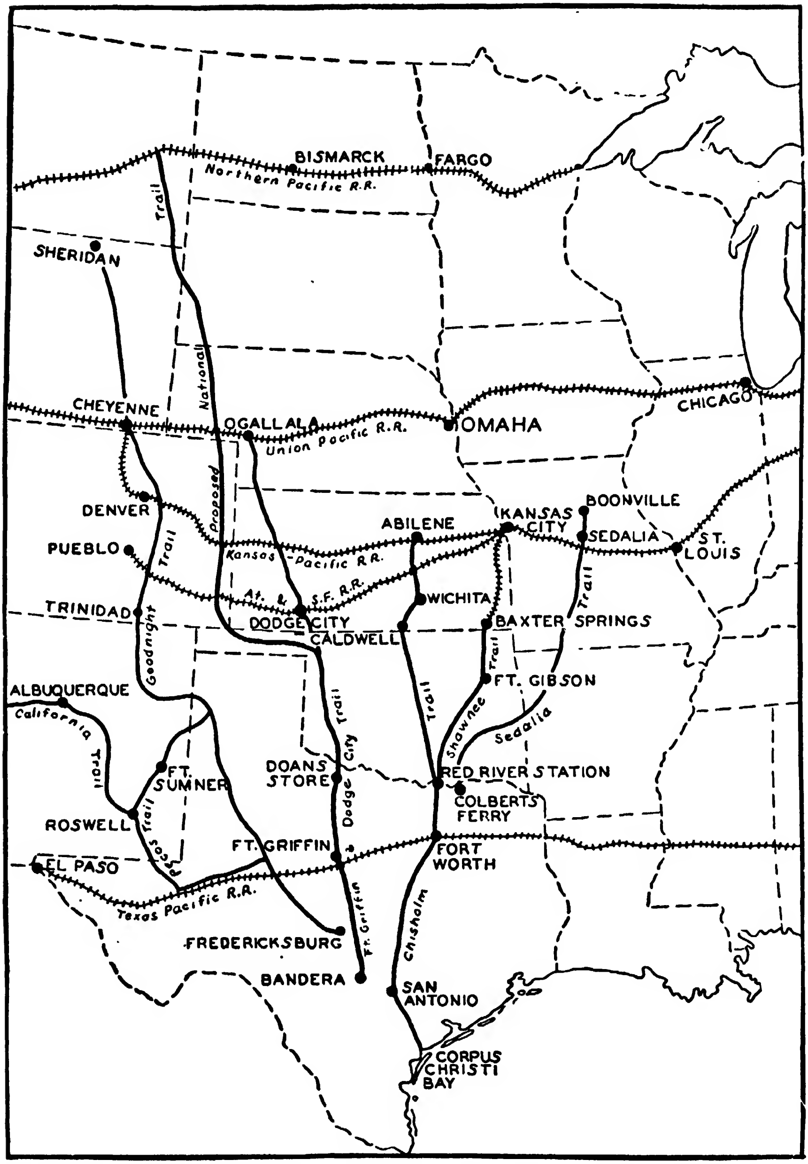

FIG. 2. Early routes of the Texas trail herds. (*Data from Walker and Lantow, New Mexico Agricultural Experiment Station Bull.* 59 *and U.S. Department of Commerce, House of Executive Documents, 48th Congress, 2d Session, Vol.* 20, 1884.)

great difficulty. The cattle were wild and unmanageable, especially while they were being moved through unfamiliar country. The numerous rivers took their toll, many cattle being drowned while crossing. Even more serious than these natural hindrances were those associated with Indians and with white settlers, who had strong feelings against the entrance of Texas livestock (12). The boon that offset these difficulties was the purchase of animals for breeding purposes by the ever-widening circle of new ranchers in the plains area.

Westward Spread of Livestock. As miners, soldiers, trappers, and others pushed into the West, it became possible for the central and northern plains to be occupied. Cowmen came in increasing numbers, and farmers were not far behind. These settlers, aided by the westward extension of the railroads, offered an excellent market for livestock. The western cattle industry boomed in the inflation period following the Civil War, and, except for a brief period of panic in 1873, phenomenal increases in cattle numbers occurred until 1885.

Cattle were selling at high prices in the eastern markets, and, as a result, speculators were encouraged by the hope of almost fabulous returns to be made from the livestock business. Immense inflow of capital took place from the eastern states as well as from abroad. This was encouraged by investment syndicates, which emphasized the great returns from the cattle industry.

As financial conditions improved, the industry expanded rapidly. The handling of finances was often lax, as was the managing of ranch properties. This laxity was often the result of the owner's living in some distant city or even in the British Isles.

Though these conditions would soon have resulted in retrenchment of the range cattle industry, an immediate collapse was precipitated by the winter of 1885-1886, a winter of unprecedented severity. The effects of this harsh weather were intensified by concentrations of cattle that had been removed from Indian territories. The result was a decimation of cattle that has been estimated to have left dead on the range 85 per cent of the animals over wide areas.

In the next year the northern plains experienced a great drought. This was followed the next winter by a severe January blizzard. Many herds were almost entirely wiped out, and others suffered tremendous losses. In the years following, much of the money was withdrawn from the enterprise. However, there did remain some individuals with a true regard for cattle raising. These were the real pioneers of the present cattle industry. From this time it was apparent that immense profits were a myth and that the future industry must settle itself on a more stable basis.

Rise of the Western Sheep Industry. Although sheep were among the animals first introduced into the New World, they were, up to the time of

the Civil War, relatively unimportant on the western ranges. There were at various times influences that stimulated the raising of sheep, such as the American Revolution and the War of 1812, but these had resulted mainly in an increase of the numbers of sheep on farms

The development of markets for wool and mutton during the eighteenth century made little progress in America, but, about the time of the War of 1812, decreases in foreign wool and the resultant increase in woolen mills in America caused rapid price increase. Mutton prices likewise increased and gave an impetus to the development of the industry. There were few sheep west of the Mississippi River in 1840. Though the industry was stimulated by the Civil War, until there were railroads to carry the wool crop, there was no material increase in range sheep production. Following this, there began a rapid development of the sheep industry. Sheepmen found much range that was admirably adapted to their herds and were attracted by the money to be made from the grazing of free lands.

During the period 1865 to 1901 the sheep industry saw a period of trail herding almost as spectacular as that of the cattle-trail herds (Fig. 3). Sheep were trailed in large numbers from California, and later from Oregon, to stock ranges farther east and to fattening and marketing points in the Midwest. During 1880, nearly 600,000 head are reported to have been trailed over well-established trail routes (33).

By 1880, there were considerable numbers of sheep, with some states possessing greater numbers than they later maintained (Table 2). By 1910, nearly all the West had reached maximum numbers.

Early-day sheepmen soon found that they could increase their grazing land by seasonal migrations, sometimes covering vast areas. They grazed their animals yearlong and moved to the high and cool mountains during the summer months and to the low and less snowy deserts during winter months.

The effect of increasing sheep numbers upon the cattle industry was severe. As compared with sheep, cattle were more difficult to move. Ranch headquarters had to be maintained, and animals became accustomed to occupying the ranges in the vicinity. This was not true in many instances of the early-day sheep operator. With headquarters consisting of a sheep wagon, a veritable home on wheels, he was prepared to move as he wished, seeking the best grass from one range to another. Although the cattlemen already were using these ranges, it did not seem to the sheepman that he was trespassing, for the land was not held by the cattlemen except by squatter's right. The cattleman felt that, by reason of previous use, the land was his to use. When the forage became scarce, the sheepman could move, whereas the cattleman was compelled to remain. The result was an intensely bitter feeling between the two classes of range operators which has not entirely passed to this day. During the early period, illegal

slaughter of cattle and sheep was common, and at times even human lives were taken in the intensely bitter contest for supremacy of the range.

Gradually, the sheepman and his herds became a part of the West, and the cattlemen realized that sheep production was a permanent industry.

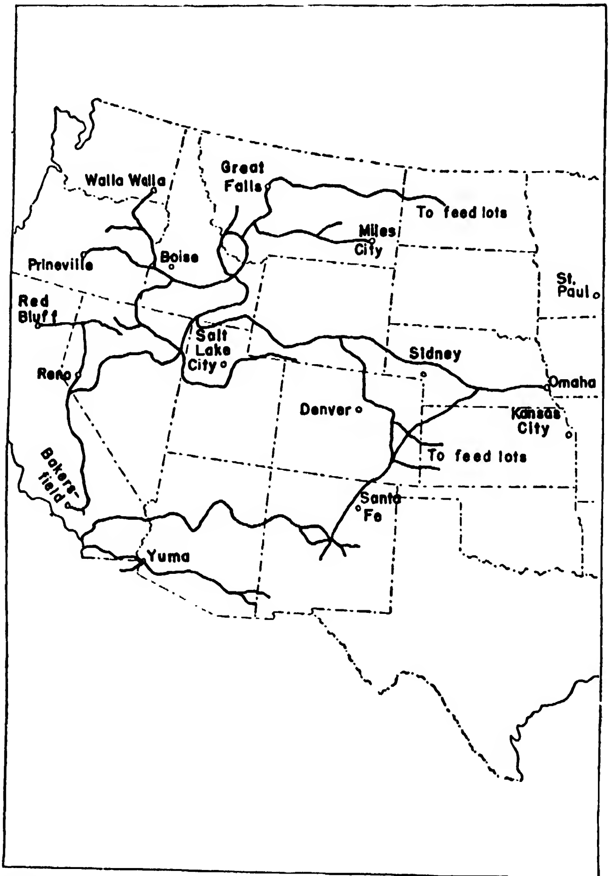

FIG. 3. Western sheep trails to eastern feed lots 1870–1900, which rivaled the early-day cattle trails in adventure and tradition. [*Data by courtesy of the Iowa State College Press, America's Sheep Trails, by Edward N. Wentworth* (33).]

Advent of the Settler. An important event to the range livestock industry was the coming of the settler to the range area. With the building of the railroad came permanent residents interested in tilling the ground, fencing and protecting land for pasturage of stock, and development of towns. Ranchers had no legal right to the range; hence, it could be homesteaded even though it was an important part of the ranch of an indi-

vidual. The passing of the various homestead laws and the removal of land by grants and withdrawals greatly decreased the range available to stockmen.

Very important to an understanding of the present grazing situation is the fact that the early cow industry spread over what are now mighty cities and great farm sections. The range industry was pushed out into the plains, mountains, and deserts. There resulted a gradual constriction of the range area. The most desirable locations next to water, the most indispensable to the rancher, were settled first. With the homestead came the wire fence, and the free movement of herds of livestock was prevented.

During the 1870's, barbed-wire fencing became cheap and readily available, and stockmen began fencing land, not only their own but also the public lands, which they used and claimed. Illegal fencing became so serious that, in 1885, Congress passed an act permitting the cutting of illegal fences.

Especially since the passage of the Taylor Act in 1934, uncontrolled use of public lands has been curtailed. Range areas are gradually becoming adjuncts of pasture and cultivated forages. The need for hay lands by the ranchers has resulted in their aiding in preemption of the range lands for agriculture. Thus, from the outside as well as from within, influences are combining to make ranching on the western range a distinctly different enterprise. Almost no straight range livestock raising is practiced today, since most operators have found supplemental feeding or part time on the farm necessary to an economical production. However, in some areas, especially the Southwest, many livestock still obtain yearlong forage from open ranges. On the range are being put more management and more fences. The western range is passing from the stage of destructive exploitation to one of development and management.

DEVELOPMENT OF LAND POLICIES

America's first settlers found a wealth of land of apparently limitless extent. This land was unowned and unsurveyed. The government soon faced the problem of developing a land policy, involving surveying and disposing of this vast resource.

The student of land management in the West will note that the government has been at fault in its land policy and is no little to blame for many present-day problems in conservation. A difficulty with these policies in the West has been that they were designed for farm land and made no provision for a settler to obtain sufficient acreage for range livestock production. This, together with the belief of many early settlers that land was inexhaustible, resulted in untold damage to the land and economic loss to the nation.

Acquisition of the Public Domain. At the time of its inception, the federal government had no land. During the period from 1781 to 1802, seven states turned their unowned lands over to the government, this land becoming the first public domain (9).

Though these original lands were the basis for development of land policy, later acquisitions hold especial interest. Most of the western lands were acquired not for the want of more land, but for indirect features. For instance, the Louisiana Purchase of 1803 was consummated to gain control of the port of New Orleans. The Northwest Territory was desirable to protect the valuable fur trade and for strategic reasons. The Southwest Territory, wrested from Mexico in 1846, was wanted largely because of the necessity for providing good harbors on the west coast. The purchase of the Gadsden Territory was made to establish a more satisfactory boundary and to facilitate the building of a railroad to the Pacific. Since there was no great value attached to the land itself, there was little concern for its judicious administration.

Land-disposal Measures. The land-disposal measures enacted by the federal government were influenced by the fact that the government possessed a great excess of land (5) but a serious shortage of cash. Three main phases of land-disposal policy can be recognized.

Sale of Lands. The first phase was marked by emphasis on the revenue to be secured; hence, early disposal acts were sales measures. Throughout this period the settler was dissatisfied because of inability to pay and because of stubborn belief in the free rights of the squatting days. The government was dissatisfied because of the slowness of sales and the increasing laxity in payment.

The failure of the many sales laws enacted during the period from 1785 to 1891 (17) may be attributed to (*a*) the government's failure to limit the maximum size of purchases, (*b*) the government's failure to establish a high enough minimum price, and (*c*) the government's adoption of credit sales.

Homestead Era. During the second phase, settlement of the country was an important motive, and the homestead acts endeavored to make acquisition of land easy and inexpensive. Even during the first period, when land was regarded chiefly as a source of revenue, there was leniency toward the squatter because of the government's desire to settle the West. Beginning about 1841, the squatter was given ever-increasing rights. Many attempts were made to obtain free-land laws, and these attempts led to the passage of the 1862 Homestead Act. This law allowed acquisition of 160-acre tracts by five years' residence upon the land and certain improvements. Unfortunately the act contained a commutation clause which enabled the settler to purchase land for $1.25 per acre after a 6-month residence. As a result of this, many of the tracts were not occupied

after commutation (31) but were sold to large lumber companies or ranchers and became part of vast enterprises.

By 1870, most of the highly productive lands of the Middle West had passed to private ownership (29). This left only the less productive semiarid lands to be settled. The allotted 160 acres was pitifully inadequate to support a family in these areas. The Enlarged Homestead Act of 1909 increased the homestead size to 320 acres in nine western states (9) and provided that one-fourth the land should be cultivated. The Three-year Homestead Act of 1912 shortened the residence period required to 3 years but missed the real issue in its failure to increase acreage.

In 1916, the Stock-raising Homestead Act was designed for the far-western lands not adapted to cultivation. This act gave stockmen 640 acres, a section supposed to be large enough to carry 50 head of cattle. The size of these range homesteads was grossly inadequate, and the provisions of the act requiring improvements and reserving water holes were unsatisfactory (9). As a result, less than half of the stock-raising homesteads were patented during the first 12 years that the act was in effect.

The failure of the government to determine and specify proper land use in the West has resulted in the plowing of thousands of acres of land unsuitable to cultivation. Almost every western state has tracts of plowed land now abandoned and virtually destroyed for grazing. The federal government is not alone responsible for these improper land policies; state and county governments likewise made many serious errors in administration and taxation.

Federal Grants. The second phase in land disposal was also marked by numerous grants to railroads and other agencies for roads, canals, and similar developments. Since land sales had fallen short of expectation as a source of national income, the government began to look upon its land as a means to national development and internal improvements (17).

Overshadowing all internal-improvement grants were the railroad grants. Grants of alternate sections of land for several miles on each side of the line were considered sound investments. Since the presence of railroads would presumably double land prices, in reality the government would lose nothing by the grant.

Of tremendous importance in land-disposition history were the school grants. Acts of 1852 and 1862 provided grants to each state of 30,000 acres for each congressional senator and representative for the support of land-grant colleges. Other grants were made for university, school of mines, and normal-school use. By 1931, there had been approximately 86 million acres granted to states under various educational-grant acts (6).

Reservations. Finally, there was a third phase during which conservation of important resources was dominant and the withdrawal of lands

was emphasized. Toward the close of the nineteenth century, it became apparent that there were areas in the West that would attain greatest usefulness if maintained in public ownership. Although a considerable area had been set aside for Indians, there were few specific reservations for the public. The realization that resources were limited and that land was being misused resulted in appreciation of the need for conservation.

In 1891, the first forest reserves were set aside by President Harrison. During the administrations of Cleveland, McKinley, and Theodore Roosevelt, further additions were made to this rapidly growing area. Since the time of Theodore Roosevelt, numerous areas have been added to the national forests and some areas have been returned to the public domain. The acreage trend, however, is still upward and the total area is now larger than the state of Texas. Much of this land is grazed by livestock, and it forms an important part of the western range.

Public lands were reserved for various purposes until, in 1934, there remained less than 200 million acres of unappropriated and unreserved lands of the original area. With the passage of the Taylor Grazing Act in that year the remainder of these lands, with a few exceptions, was withdrawn from entry. Thus culminated a long struggle to secure the adoption of measures that would provide for some form of control over the federal lands.

As early as 1899, efforts had been made in Congress to secure legislation permitting the leasing of public domain to stockmen. Between 1906 and 1920 many other measures with similar objectives were introduced in Congress (3).

Initially, the Taylor Grazing Act provided for 80 million acres to be included in grazing districts. Now over 160 million are included in organized grazing districts of which $1\frac{3}{4}$ million are private and other leased lands.

Many federal land reserves are of importance to range management only as they might influence the use of land for grazing. Large areas of national parks and monuments are not open to grazing by domestic stock, though they support thousands of big-game animals and therefore require careful range management. Indian reservations occupy over 57 million acres of land, almost all of which is valuable as grazing land. Although this land is grazed largely by Indian-owned stock, some is rented by white stockmen. Other important land reserves include water-power sites, reservoir sites, mineral deposits, army and navy reserves, and public water reserves. In total, reserves now represent over 455 million acres of land, most of which is in the West. The disposition and present administration of the public lands and the approximate acreages are shown in Table 3.

The United States in 1950 still retained some 407.4 million acres of the

TABLE 3. DISPOSITION AND PRESENT STATUS OF THE PUBLIC-DOMAIN LANDS OF THE UNITED STATES, EXCLUSIVE OF ALASKA

	Thousands of acres
Lands, title of which has passed from the United States, 1951 (5):	
Homesteads	285,000
Cash sales and miscellaneous disposals	430,000
Grants to railroad corporations	91,000
Grants to states	225,000
Total area disposed	1,031,000
Public lands in the United States, 1950 (8):	
Bureau of Land Management	179,093*
Forest Service	160,582
Bureau of Indian Affairs	57,280
National Park Service	13,956
Bureau of Reclamation	9,928
Soil Conservation Service	7,415
Fish and Wildlife Service	4,129
Farmers Home Administration	14
War Department	19,332
Navy Department	2,126
Agricultural Research Service	166
Tennessee Valley Authority	459
Other Agencies	1,152
Total	455,632

* About 158.3 million reserved in grazing districts. The remaining 20.7 million is small isolated tracts or unreserved public domain.

original public lands and 48.2 million that had been regained from private ownership (8). This totals almost one-fourth the country's area. Federal reservations constitute 53.9 per cent of the area in the 11 western states (Table 4). These vast public areas are considered to be a permanent possession of the government, although there are occasional vigorous movements to convert parts of this land into private ownership.

TABLE 4. PERCENTAGE OF LAND IN 11 WESTERN STATES UNDER FEDERAL OWNERSHIP, 1945 (28)

State	Percentage	State	Percentage	State	Percentage
Arizona	73.6	Montana	37.2	Utah	72.[illegible]
California	45.3	Nevada	85.2	Washington	35.3
Colorado	37.9	New Mexico	44.5	Wyoming	52.0
Idaho	65.3	Oregon	52.9	11 States	53.9*

* About 406.7 million acres. Federal lands comprise about 24 per cent of the total area of the United States.

In all phases of land disposal there was evidenced only a striving toward adjustment to existing conditions. There was no forward-looking policy designed to anticipate and meet future situations. Thoughtful planning and scientific outlook resulted only as time brought to light the errors of the early policy.

Results of Federal Land Policies. One result of the government's failure to regulate use of the public land was a serious reduction of land values. Over the period from about 1860, when cattle grazing on the public domain became general, until 1934, when the Taylor Grazing Act was passed, little provision was made for administering the grazing of western land. Notable exceptions were certain reserves such as the national forests. The result of this general lack of supervision of public lands was an intense competition to secure as much as possible from the lands. Since one individual had as much right on the area as another, there was nothing to prevent him from placing stock on a range, even though it might already be supporting all the animals the forage justified. Further, there was always a race to get to the range first and thus to graze the choice forage. This resulted in complete disregard of wise seasonal grazing practices. Such conditions could only result in extensive damage to the ranges.

The land laws also contributed to range deterioration, since the amount of grazing land that a person could acquire legally was insufficient to care for a herd of a size to support a family. This encouraged heavy use of the owned range and made necessary heavy grazing of public ranges in the vicinity. Likewise, permitting land to be taken up for crop production in areas that were unsuited for the purpose led to much damage. In most cases, it was not discovered, or not admitted, that the land was not sufficiently productive for cropping until after several years of cultivation. During that time, the forage was destroyed and the land subjected to erosion, which was sometimes so severe as to interfere seriously with revegetation after abandonment.

Similarly, the method of dispensing lands to the states, the public-school lands particularly, was such as to complicate any effort at management. These tracts, scattered as they were throughout the state in 640-acre units, were impossible of administration. Had they been economic grazing units, they undoubtedly would have been used more effectively.

The Bureau of Land Management and the Forest Service, likewise, are handicapped by the existence of small tracts of patented land throughout an area that they administer. These areas are owned by individuals or corporations having in many instances too little land to justify close supervision. Obviously such conditions make difficult any efforts at control of land use (Fig. 4).

Though the land picture in western America is still immensely compli-

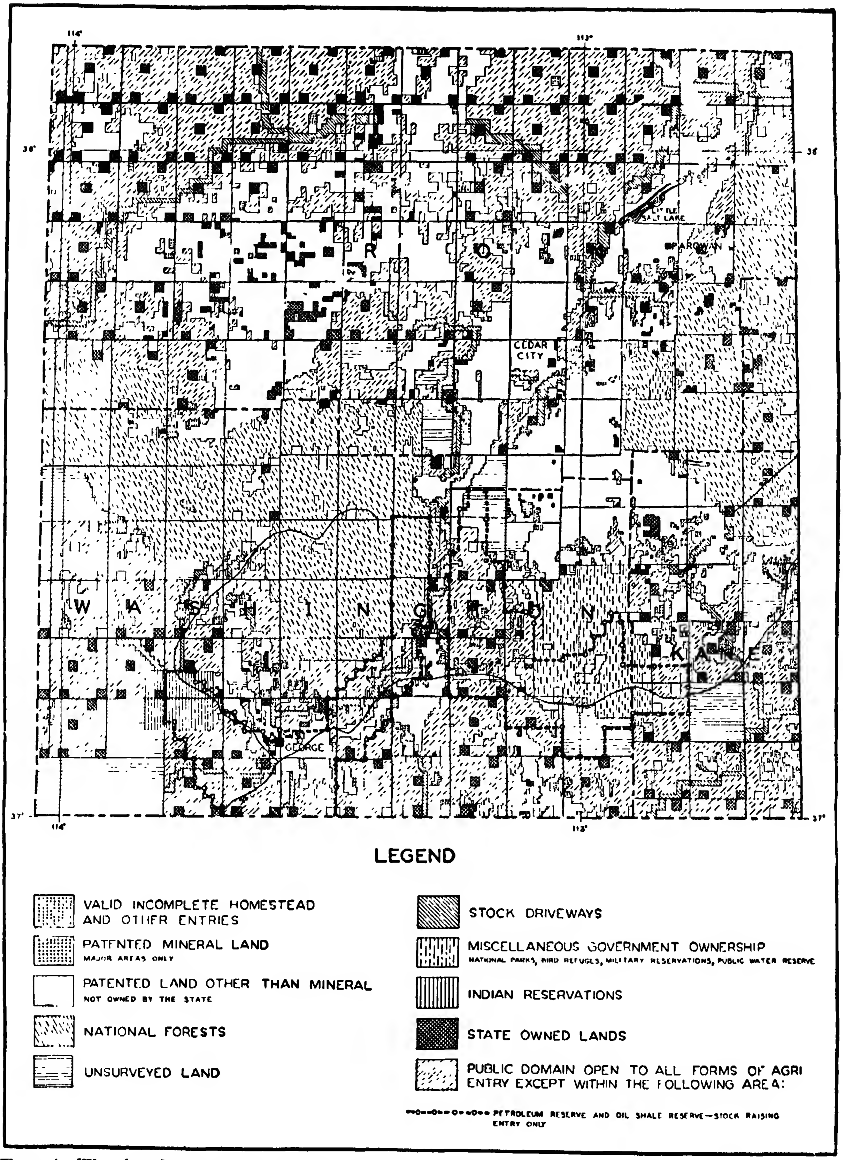

FIG. 4. The landownership pattern of an area in southern Utah, showing the great complexity of ownership and the minute subdivision of land which faces the administrator of range land in the West.

cated, there are many promising legislative and administrative programs that have been initiated since the beginning of the twentieth century. Through planned programs founded upon the principle of conservation and aiming to correlate the use of public lands with the demands of the citizens and with the use of private lands, a challenging opportunity exists to bring order out of chaos.

IMPORTANCE OF RANGE INDUSTRY TODAY

Grazing in the United States. Over 53 per cent of the land area in the United States is grazed by livestock (Table 5). About half the remaining area contributes to the maintenance of livestock through the production of forage crops. In addition, there is wide usage of both native and cultivated lands by wildlife— a factor of great magnitude and importance.

Estimates (19) based upon total digestible nutrients required to support all livestock in the United States compared to total digestible nutrients supplied by all harvested crops show harvested crops supply 45 per cent of the feed requirements, leaving 55 per cent to be supplied by range and pasture lands. Since total market value of harvested feeds in the United States (1950) is 8,715 million dollars, it is calculated that feed supplied by range and pasture lands is valued at 10,632 million dollars.

TABLE 5. AGRICULTURAL DISPOSITION OF LAND IN THE UNITED STATES, SHOWING ACRES GRAZED AND UNGRAZED, MILLIONS OF ACRES, 1950 (25)

Land type	Grazed	Ungrazed	Total
Unforested range and permanent pasture	631	0	631
Forest and woodland	320	286	606
Cropland	69*	409*	478
Unused for agriculture	0	189	189
Total	1,020	884	1,904

* Sixty nine million acres of cropland is used for grazing only. Four hundred nine million acres is used primarily for crops, but these may be grazed *after* the crop harvest.

The range livestock industry, though not confined to the West, is much more important in that region of the United States. The 17 states lying, essentially, west of the 100th meridian are known as the *range states* and make up the *western range*. Though this region includes vast areas of ungrazed forest and farm land, it is and must remain predominantly range. Western agriculture must be founded upon this fact. These states have a lower precipitation than the eastern states, and cultivation is prohibited over vast areas because of shallow, rocky, or saline soils.

Statistics for Jan. 1, 1950, show over 74 per cent of the sheep and 45 per

TABLE 6. THE 17 WESTERN STATES IN ORDER OF PRODUCTION OF CATTLE, SHEEP, AND TOTAL ANIMAL UNITS, WITH ACRES PER ANIMAL UNIT, JAN. 1. 1950

State	Number of cattle (thousands)*	State	Number of sheep (thousands)*
Texas	8,116	Texas	6,605
Nebraska	3,843	Wyoming	1,921
Kansas	3,588	Colorado	1,782
California	2,70[illegible]	California	1,75[illegible]
Oklahoma	2,580	Montana	1,584
South Dakota	2,454	New Mexico	1,371
Colorado	1,800	Utah	1,329
Montana	1,726	Idaho	1,065
North Dakota	1,495	South Dakota	869
New Mexico	1,178	Kansas	802
Oregon	1,085	Oregon	689
Wyoming	991	Nebraska	588
Idaho	939	Nevada	448
Washington	851	Arizona	423
Arizona	818	North Dakota	398
Utah	588	Washington	299
Nevada	530	Oklahoma	145
Total	35,291		22,077

State	Number of animal units† (thousands)	State	Total land area, thousands of acres	Acres per animal unit
Texas	9,437	Nebraska	49,157	12.41
Nebraska	3,961	Kansas	52,335	13.96
Kansas	3,748	Oklahoma	44,396	17.07
California	3,060	Texas	167,964	17.79
South Dakota	2,628	South Dakota	49,196	18.71
Oklahoma	2,609	North Dakota	44,917	28.54
Colorado	2,156	Colorado	66,341	30.77
Montana	2,043	California	99,617	32.55
North Dakota	1,574	Wyoming	62,431	45.37
New Mexico	1,452	Montana	93,524	45.77
Wyoming	1,376	Idaho	53,347	46.30
Oregon	1,223	Washington	42,775	46.95
Idaho	1,152	Oregon	61,188	50.03
Washington	911	New Mexico	78,402	53.99
Arizona	903	Utah	52,598	61.59
Utah	854	Arizona	72,838	80.66
Nevada	619	Nevada	70,285	113.54
Total or average	39,706		1,161,311	42.12

* Data from U.S. Department of Agriculture (26).

† Calculated at five sheep or one cow equaling one animal unit.

cent of all the cattle in the United States in the 17 western states (24). The far-western states are predominantly sheep-producing, whereas the midwestern states are cattle-producing (Table 6). Midwestern states produce more livestock than the far-western and materially more livestock per acre, despite a lesser percentage of their area devoted to livestock.

A vast wealth comes to the western states from livestock enterprises. A slight majority of the agricultural income in the 17 western states is derived from cultivated crops rather than livestock because of high productivity on cultivated land. However, many agricultural areas of the West are so distant from markets that crop marketing other than through livestock is not feasible; hence, a considerable portion of the crop returns is collected through livestock, making crop value dependent upon livestock. Range production is one of the most basic of all industries in the West, and its importance cannot be overemphasized.

The southeastern and south central states have greatly increased cattle populations and range-livestock emphasis since about 1935. This was stimulated by decreased cotton acreage and increased fertilizing, supplementing, grass seeding, and livestock improvement. An example of this increase is Florida which had 780,000 cattle in 1938 contrasted with 1,503,000 in 1951.

The southern coastal area from Virginia to east Texas is generally pine forest, bottomland hardwoods, and coastal prairie. Cattle, hogs, and a few sheep graze these ranges yearlong. The population of over 7.5 million cattle (4) is already an important factor in national livestock production, and this area may soon rival the West as a range-livestock-production center.

Place of the United States in the World's Meat Production. The Americas rank high in livestock production, North and South America combined producing 30 per cent of the world's cattle and 21.5 per cent of the sheep (24). India leads in numbers of cattle and Australia in numbers of sheep (Table 7). The United States with 80 million cattle has slightly over 10 per cent of the world total. With over 30 million head of sheep, the United States ranks seventh in production, having 4.2 per cent of the world total.

For the aggregate area of all countries of the world, there are 13.6 head of cattle and 12.6 head of sheep per square mile. Europe exceeds all other divisions in density of cattle and sheep. North America is low in cattle density and extremely low in sheep density (Table 8). The United States, however, has 26.6 cattle per square mile compared with the world average of 13.6, and 10.2 sheep compared with the world average of 12.6.

The ratio between total head of livestock and human population is one of the most significant factors in determining the extent and possibilities of development and production and exportation (13). Oceania (Australia

and New Zealand) and South America surpass all other divisions in production per unit population, Oceania producing 1,509 cattle nd 11,243 sheep per 1,000 population (Table 8). The countries with large attle and sheep surpluses are in South America, South Africa, and Oceania. The

TABLE 7. THE LEADING COUNTRIES IN THE WORLD IN NUMBERS OF CATTLE AND SHEEP, 1951
Data from U.S. Department of Agriculture (24)

Country	Thousands of heads	Percentage of world total
Cattle:		
India	177,000	22.4
United States	80,052	10.1
U.S.S.R	56,000	7.1
Brazil	46,400	5.9
Argentina	42,000	5.3
Pakistan	31,000	4.0
China	23,600	3.0
France	15,404	1.9
Australia	14,597	1.8
Mexico	14,500	1.8
Union of South Africa	12,242	1.5
World total	790,900	100.0
Sheep:		
Australia	112,891	15.4
U.S.S.R	78,000	10.6
Argentina	47,000	6.4
India	38,900	5.3
New Zealand	33,852	4.6
Union of South Africa	31,908	4.3
United States	30,743	4.2
Uruguay	25,000	3.4
Turkey	23,071	3.1
Spain	23,000	3.1
China	22,000	3.0
United Kingdom	20,430	2.8
World total	733,900	100.0

United States has 531 cattle and 204 sheep per 1,000 population. Cattle numbers appear to be rising and sheep numbers falling in the United States (Table 9).

Despite high production of meat per unit of population, the United States is a major importer, ranking fifth among the major nations for beef importation (16). The United States imports a small amount of

mutton and lamb but takes no important part in world trade of this product. Although meat imports in this country (mostly beef and veal) have risen from 1.5 million pounds in 1900 to about 529 million in 1952, this represents only a little over 2 per cent of domestic production (10).

Table 8. Ratio between Human Populations and Livestock Numbers; Density of Livestock per Square Mile in Some Leading Divisions of the World, 1951

Division	Number per square mile		Number per 1,000 population	
	Cattle	Sheep	Cattle	Sheep
Africa	7.2	7.8	460	499
Asia (exclusive of U.S.S.R)	27.3	13.9	224	113
Europe (exclusive of U.S.S.R.)	52.3	59.7	251	287
North America	12.1	4.1	527	177
Oceania	6.0	11.4	1,509	11,243
South America	18.8	17.5	1,150	1,070
U.S.S.R	6.5	9.1	278	387
World average	13.6	12.6	328	304

How Range Production Influences Other Industries. In considering the importance of the range to the agriculture and industry of a state, one is impressed by the relationships between the grazing of livestock and the operation of other industries.

One of the most important industries related to the livestock industry is farming. With increased production of forage crops on farms since 1935 and a shortened range grazing season on federally controlled ranges, livestock through most of the West are dependent upon farm feed during the winter and spring, at least on emergency occasions.

Livestock make use of many residues and by-products of the farm that otherwise would remain unused. Many livestock are fed part of the year on grain stubble, cotton seed, sugar-beet by-products, and numerous other farm products to bring increased returns to the farm operator. In remote areas, livestock are the only economic market for farm crops; without livestock, such areas would not be farmed. The western ranges contribute a large part of the stock that are fattened on both eastern and western farms. The demand of livestock has a profound effect upon the maintenance of crop prices and, hence, upon agricultural welfare.

Direct relationships exist between the livestock industry and banks, insurance companies, and loan corporations. Firms of this type have suffered crushing losses because lands upon which their investments depended became almost valueless through depletion and erosion. Financial

TABLE 9. CATTLE AND SHEEP NUMBERS IN THE UNITED STATES, JAN. 1, 1913–1954 (13, 24, 30)

Year	Cattle number* (thousands)	Sheep number (thousands)
1913	58,737	37,773
1921	67,264	36,922
1922	66,156	36,803
1923	61,507	37,139
1924	62,150	38,543
1925	60,576	40,363
1926	58,178	42,415
1927	57,322	45,258
192	58,877	48,381
1929	61,003	51,565
1930	63,030	53,233
1931	65,770	53,974
1932	70,214	53,075
1933	74,262	53,713
1934	68,529	52,245
1935	67,929	52,022
1936	66,448	52,558
1937	65,930	52,918
1938	65,249	51,063
1939	66,029	51,348
1940	68,309	52,107
1941	71,755	53,920
1942	76,025	56,213
1943	81,204	55,150
1944	85,334	50,782
1945	85,573	46,520
1946	82,434	42,436
1947	81,207	37,818
1948	78,126	34,827
1949	78,298	31,654
1950	80,052	30,743
1954†	94,677	30,902

* An estimated one-third of these animals are milk cows.

† Preliminary, U.S. Department of Agriculture, Agricultural Marketing Service.

organizations have expressed themselves as vitally interested in better range-land management.

The relationship between livestock production and such industries as packing and slaughter, leather manufacture, wool and woolen mills, railroads, and trucking is evident, but many other industries are indirectly influenced by a thriving livestock industry. Many industrial centers are maintained predominantly by the livestock industry, and range conditions and livestock prices are reflected in community prosperity.

Importance of Range Management in Soil and Water Conservation. One important function of natural vegetation is the protection of the

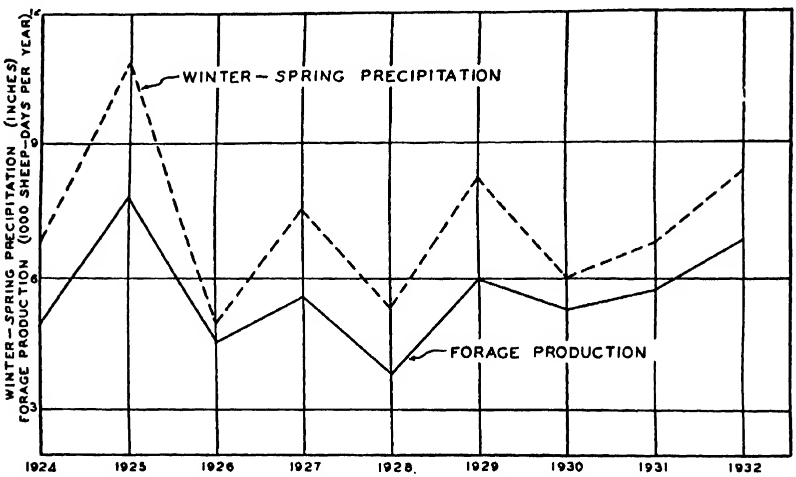

FIG. 5. Unusually close correlation may exist in certain areas between vegetation production and precipitation. [*Data from Craddock and Forsling* (7).]

watersheds and the conservation of soil and water. Plants control soil loss and retard runoff to make these resources more available for man's use. Proper range management has as one of its most important goals water and soil conservation.

As the West is generally deficient in precipitation, and water is the limiting factor to plant production (Fig. 5), the yield of cultivated and uncultivated land is closely related to the effective moisture that penetrates the soil. Since over half the area is classed as arid or semiarid, it is evident that water conservation is of especial importance (Fig. 7).

Most of the western cultivated land is irrigated; and the water comes from range lands and is a product of the range. Maintenance of good range conditions is a requisite to optimum production from these watersheds. Improper management results in rapid liberation of runoff following storms and high early-spring flow rather than gradual liberation.

The value of clean water to a city cannot be overstated. Once the watershed and its protective vegetation cover are destroyed, there is almost no limit to the expense that a city may be willing to meet to improve these conditions or secure another watershed. Many western towns have prohibited grazing upon watersheds that yield their culinary water because they realize their dependency upon the plant cover for a sustained and high-quality flow.

A direct result of improper range use is flooding. Floods are made the more damaging by the fact that man has built great cities near the major rivers, and areas of intensive settlement are in the direct path of many serious floods. Neither proper range management nor any other land management will prevent all floods, but improper range use may seriously increase flooding.

Multiple Land Interests. Demands on western lands include such apparently remote things as timber production, picnicking, skiing, fishing and hunting, and even just viewing scenery. All these activities are related indirectly to range use. Range livestock production, especially on public land, is part of a *multiple-use* picture often of great complexity. For example, heavy grazing increases weedy plants. These form a habitat or breeding place for the leaf hopper. This insect, in turn, carries curly-top disease to crop plants such as sugar beets, tomatoes, and beans. Range misuse thus increases crop-plant disease. Also, false toadflax is a host plant for a certain pine tree rust. Apparently misuse of range land increases the quantity of false toadflax and, in turn, has resulted in great increase in the forest-tree disease. Range managers must keep in mind a great variety of interrelated industries and problems to enable best use of the land as a whole. Grazing is but one use of most western ranges.

FUTURE OF RANGE INDUSTRY IN THE WEST

Land use can be regarded as an expression of natural physical factors such as climate and soil, man's development of natural factors, and the social and economic conditions existent. These factors, especially the natural physical factors, are relatively constant and inherent in an area; hence, except after periods involving major reclamation developments, profound changes in land use are rare. Although a belt of grazing land preceded early settlers as they moved across the country westward, this belt was always later tilled and the grazing moved farther westward. Only when the untillable Far West was reached did people realize that range grazing was a permanent land use. Only then was range management as a science born (21). Today we accept range grazing as a part of America's permanent agricultural endeavor.

Natural Factors as They Influence Range Use. Climate, particularly precipitation, governs farm and range production. The climate of the West is not only arid but also highly variable, making stability of production difficult. Though climatic fluctuations of both long and short duration occur, there is no likelihood of changes sufficient to alter conditions that now exist. Through better use of the water that flows from mountain areas, both by better storage and by more efficient distributing systems, improvement may be made in agricultural production, but such adjustment will alter but little the present pattern of land use. There will be minor fluctuations in range production, dependent, chiefly, upon current conditions; there will be minor changes in land ownership and use; but large production increases are not expected. Indeed, it is not likely that increases will more than balance decreases in areas of low productivity that are being retired from use.

TABLE 10. ESTIMATED YEARLY PRODUCTION AND PER CAPITA CONSUMPTION OF MEATS IN THE UNITED STATES, 1900–1950 (23, 24)

Year	Production, millions of pounds				Consumption, pounds				
	Beef	Veal	Lamb and mutton	Pork	Beef	Veal	Lamb and mutton	Pork	Total meats
1900	5,628	397	493	6,329	67.0	5.2	6.5	71.9	150.6
1905	6,504	556	530	6,629	70.9	6.6	6.3	70.6	154.4
1910	6,647	667	597	6,087	70.5	7.2	6.4	62.4	146.5
1915	6,075	590	605	7,616	57.1	6.0	6.2	67.3	136.6
1920	6,306	842	539	7,648	59.1	8.0	5.4	63.5	136.0
1925	6,878	989	603	8,128	60.0	8.6	5.3	67.3	141.2
1930	5,907	789	823	8,479	48.8	6.4	6.7	67.0	128.8
1935*	6,592	1,007	884	5,954	53.1	7.9	6.9	48.5	116.4
1940	7,175	981	876	10,044	54.7	7.4	6.6	73.0	141.7
1945	10,275	1,661	1,054	10,697	59.0	11.8	7.3	66.3	144.4
1950	9,543	1,216	599	10,751	63.0	7.9	4.0	68.8	143.7

* Not including beef, veal, and mutton from animals slaughtered for government account in 1935.

Range lands can undergo certain developments that may increase their production capacity. For example, many ranges do not have sufficient livestock water to permit full use of the forage. Others can be made more productive by development of trails and by better herding. The possibilities of increasing forage by better grazing systems, by correct season of use, and by seeding should not be disregarded. Great hope is held that improved practices will be forthcoming. Knowledge of farming and ranch-

ing methods is developing, and with it will come an improvement in management and planned use.

Economic Factors as They Influence Land Use. A factor that influences the use of land and the position of the nation with respect to an industry is the demand of the consuming population. People are the consumers of products, and the number of people that require any commodity determines the place it will have in commerce. Estimates vary widely as to the future population of the United States.

It is possible that changes in consumption due to changes in dietary habits and economic levels (22) will influence meat supply and demand relationships. It is interesting to note the trends in meat consumption in the United States as shown in Table 10. Present indications are that the result of many and sometimes opposing factors will be to leave land-use patterns essentially unaltered for some time to come.

In addition, there are contemplated changes in land use in the United States that have some bearing upon the land available for grazing. It is believed that some of the present cropland will be retired from cultivation, but no great increase in range-land acreage is expected. Hence, increased demands necessitate fuller use of the areas being grazed. Certainly satisfying the American demands for meat is a challenge to livestock producers and range managers.

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CHAPTER 2

PHYSICAL FEATURES OF THE WESTERN UNITED STATES AFFECTING RANGE USE

A student of range management cannot understand the problems of managing ranges without a knowledge of the physical characteristics of the West. Not only do these physical features determine vegetation available for livestock, but they determine the manner and degree of grazing possible. These physical features include climate, soil, and topography.

Soil is produced by the action of climate and vegetation upon the parent-rock materials. Adequate precipitation makes luxuriant vegetation, which, in turn, makes deep fertile soil. Conversely, under extreme aridity, the soil is poor. Climate, and more specifically precipitation, can be regarded as the most important single factor influencing range production.

Topography not only influences livestock movements, but it affects plant growth also. On favorable exposures, conditions for plant growth are above the general average of the area. On unfavorable exposures, such as very steep slopes, erosion and runoff may be severe; hence, soil and moisture are unfavorable. Especially on hot south-facing slopes, vegetation may be very sparse.

Physical features, particularly climate and soil, determine the nature of the vegetation. They cause grass to grow in the plains, forests to grow in the mountains, and shrubs to grow in the deserts.

Physical conditions in the West generally are unfavorable to luxuriant plant growth. Range land frequently occupies steep rocky hillsides, dry shallow plains, or cold wind-swept prairies and is inherently limited in production. A luxuriant growth cannot be expected even under the best management. This concept is important in managing range land.

PRECIPITATION

Precipitation has a direct influence upon the grazing capacity of range land (Table 11). Roughly 20 per cent of the area west of the 100th meridian has an average precipitation of less than 10 inches. An additional 25

per cent, or a total of 45 per cent, receives less than 15 inches. Roughly 30 per cent of the area receives 15 to 20 inches; 12 per cent, 20 to 30 inches; 4 per cent, 30 to 40 inches; 2 per cent, 40 to 50 inches; 2 per cent, 50 to 60 inches; and 5 per cent, over 60 inches (Fig. 6). Almost half the West receives precipitation too low for dry-farm production, and most of the regions of high precipitation are mountain areas where topography prohibits cultivation.

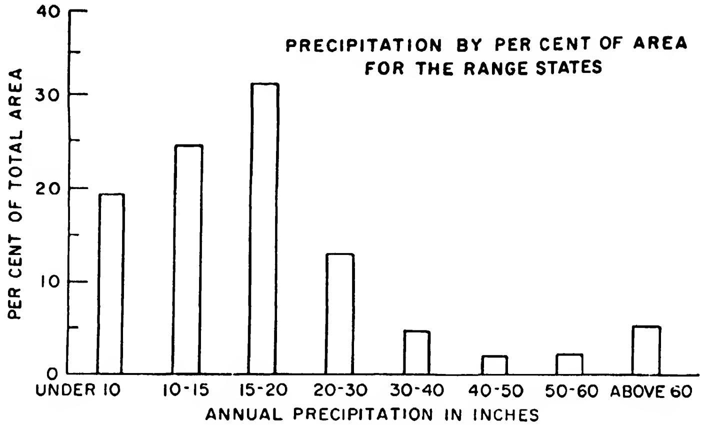

FIG. 6. Average precipitation of that area of the United States lying west of the 100th meridian, by percentage of total area.

Geographic Distribution of Precipitation. The geographic distribution of precipitation is influenced by the distance from oceans and by topographic features that influence prevailing air currents (Fig. 7). Tremendous precipitation differences may exist within a few miles. Pikes Peak, Colo., at an altitude of 14,100 ft. above sea level, receives an average precipitation of 30 inches; the subalpine forests, 25 inches; the lower-elevation forests, 22 inches; and the plains at the base of the mountain,

TABLE 11. THE NUMBER OF ACRES OF RANGE IN GOOD CONDITION REQUIRED TO SUPPORT ONE COW FOR ONE YEAR IN AREAS RECEIVING VARIOUS ANNUAL PRECIPITATIONS (11)

Precipitation, Inches	Grazing Capacity, Acres per Animal per Year
0 5	No grazing
5 10	60–200
10 15	35– 80
15 20	25– 45
20 25	12– 35
25–30	8– 15
Over 30	3– 12

some 6,000 ft. in altitude, an average of about 15 inches (14). Even greater differences exist in the state of Washington, where parts of the Big Bend region in the center of the state receive 5 to 7 inches and parts of the Cascade Range 100 miles westward receive over 120 inches per year.

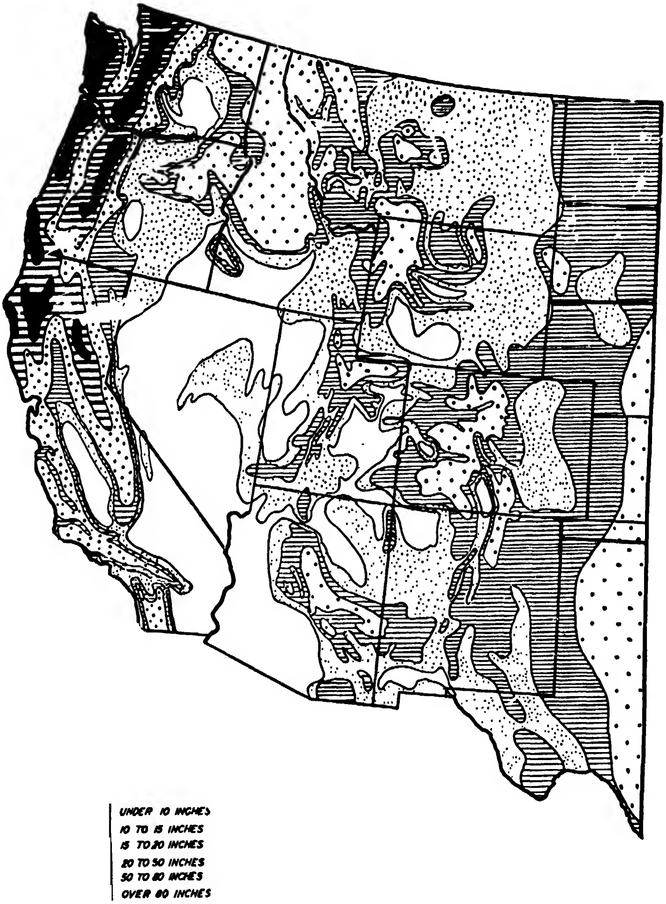

FIG. 7. Average annual precipitation for that part of the United States lying west of the 100th meridian. (*Data from U.S. Weather Bureau.*)

High-elevation ranges, in general, have a greater precipitation and a more luxuriant vegetation than low ranges, although there appears to be an elevation above which a decrease is probable (7). The average annual precipitation for Utah's weather stations below 4,000 ft. altitude is 9.80 inches; those between 4,000 and 5,000 ft. receive 12.55 inches; those between 5,000 and 6,000 ft. receive 13.57 inches; and those above 6,000 ft.

receive 15.28 inches. The annual precipitation over the high westerly exposures of the Wasatch Range averages nearly 10 times that on certain deserts west of Great Salt Lake.

Annual Variation in Precipitation. Low precipitation in the West is made more serious by great variability. Monthly and yearly precipitation both deviate widely from their mean, and prolonged periods of above or below normal are common. This variability is one of the most vital and complicating factors to be dealt with in range management.

Monthly-drought-probability calculations indicate that summer droughts are frequent in the western states, especially west of the Rocky Mountains. Winter drought, obviously less important than summer drought, is especially likely in the Great Plains (2).

Calculations of the number of years of precipitation significantly below normal (less than 85 per cent of normal annual precipitation) in the West show the greatest frequency of deficient precipitation in the Southwest, where over 40 per cent of the years are deficient (8). In the Northwest, only 10 to 20 per cent are deficient. Over the majority of the West, significantly subnormal precipitation occurs in 20 to 40 per cent of the years. Further, these studies show that most years are below average in precipitation; therefore, in studying charts showing the average amounts of precipitation, the fact that the amounts shown are usually available for plant development in fewer than half the years should not be lost sight of (8).

Study of the tendency toward a long series of below-average-precipitation years indicates likelihood to be especially high in the northern third of the 17 western states and especially low in the southern third (3). An exception is a major low spot in eastern Wyoming and western Nebraska.

It is characteristic of precipitation to vary in wavelike progression, although the time involved is decidedly irregular and seems to follow no known laws (9). Table 12 shows the precipitation averages of the western states during the famous drought period of 1933-1935. With the exception of Washington, all states were significantly below normal, many being less than two-thirds normal. This moisture deficiency was unprecedented since man has studied weather in the West.

Droughts such as this are made the more serious in that they generally are accompanied by high temperatures and low humidities. Temperatures higher than ever before recorded accompanied the 1934 drought in many areas, and high temperatures existed for long periods. This great drought period, and the lesser droughts both preceding and following, had profound influences upon range conditions in the West. In numerous areas, established vegetation underwent complete change, even though grazing was not heavy. Recovery involved 5 to 15 or more years so profound were the effects.

TABLE 12. AVERAGE PRECIPITATION FOR THE 17 WESTERN STATES DURING THE HISTORIC 1933–1935 DROUGHT IN PERCENTAGE OF LONG-TIME NORMAL (12)

State	1933	1934	1935
Arizona	86	76	112
California	84	75	92
Colorado	92	66	96
Idaho	103	89	68
Kansas	82	74	106
Montana	107	77	72
Nebraska	90	63	100
Nevada	74	79	96
New Mexico	89	70	102
North Dakota	79	56	105
Oklahoma	93	83	112
Oregon	107	98	78
South Dakota	91	65	81
Texas	84	86	121
Utah	79	71	81
Washington	137	111	84
Wyoming	85	76	86

From 1950 to 1955, drought was more or less general in the Southwest, causing extreme vegetation depletion, soil blowing, and virtual economic collapse of the livestock industry in local areas.

Since 1922 the U.S. Department of Agriculture has estimated range condition at monthly intervals in the 17 western states. Statistical analyses (1) show range conditions to be closely correlated to precipitation during the current year, and, in the northern plains, it is even more closely correlated when precipitation of the preceding year is added. This study suggests that precipitation can be used to forecast forage production several months ahead in about half of the West, especially in the northern and central Great Plains.

Seasonal Distribution and Character of Precipitation. The seasonal distribution of precipitation is exceedingly varied (Fig. 130, page 365). This distribution is important in that it determines whether vegetation receives moisture during its growing season or whether the moisture must be stored in the soil for use at some later period. In the Southwest, where temperatures are such as to allow growth almost any time that precipitation permits, the distribution of precipitation is of lesser importance than farther north, where plants cannot grow during winter.

Three distinct distribution types can be noted in the West and are characteristic of large areas: (*a*) The first of these is the winter precipitation or Mediterranean type such as is found in California (Fig. 8), where in places there is practically no precipitation during July and August.

(*b*) A second type of precipitation distribution is characteristic of the northern Great Plains region, where the heaviest precipitation occurs in spring, usually April to June. (*c*) A third, the late-summer type, is characteristic of the Southwest, especially Arizona and New Mexico. Here, July

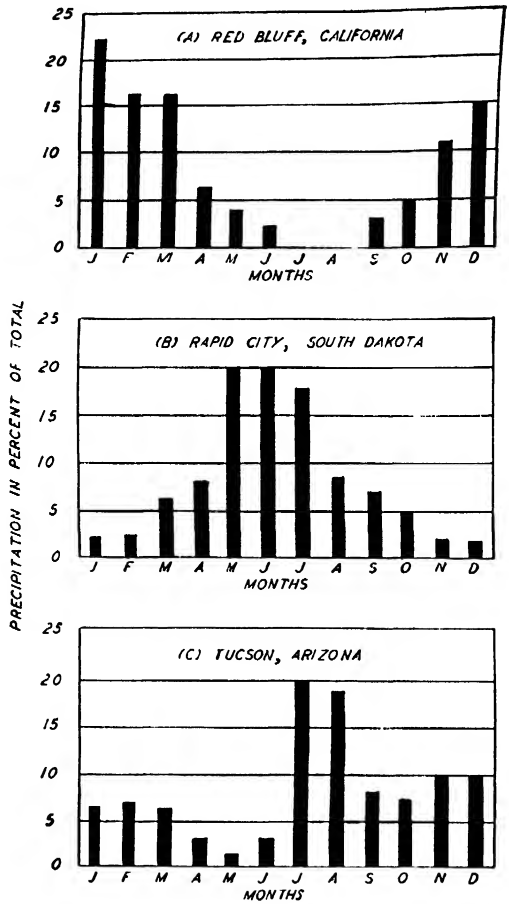

FIG. 8. Distribution of precipitation, in percentage of total, for areas typical of each of the three types of precipitation found in the West: (*A*) winter precipitation; (*B*) spring precipitation; and (*C*) late-summer precipitation. [*Data from U.S. Weather Bureau* (9).]

and August, or even September, are the periods of heavy precipitation, and early spring, often, is very dry.

The three types of precipitation grade from one to the other, but they can be delimited fairly accurately. In the northern part of the United States, the area west of the Rocky Mountains is of the winter type, and

that east of these mountains is of the spring type. There is a wide transitional zone in the intermountain region with a slight majority falling in the winter. This zone is said to have a *sub-Pacific* type of precipitation. *Arizona, New Mexico, and western Texas are the areas where late-summer precipitation is dominant.*

The effectiveness of precipitation cannot be determined by averages alone. The intensity of individual storms is of great importance. For instance, *very light rains are of literally no value to plants* because moisture is evaporated so rapidly, especially if it falls on hot soils. Unless precipitation percolates into the soil to a depth where it is available to plant roots, it is of little importance. Under certain conditions, especially on clay soils, showers of less than 0.15 inch are of no value in increasing soil water (6). In parts of the Southwest, rains of less than 0.5 inch are insufficient to promote growth of range grasses unless preceded or followed by more effective rains (11). Similarly, intense rains may be of reduced value if the soil is unable to absorb all the precipitation. As the intensity of the rain deviates above or below an optimum, its effectiveness is diminished.

Frequently, long periods may elapse without usable rainfall. In Reno, Nev., during 1934, a period of 3 months contained only 2 days in which over 0.01 inch of precipitation was recorded. Yuma, Ariz., during the same year had 4 consecutive months without measurable precipitation. Only 12 days out of the year had over 0.01 inch of precipitation (9). At Kelton, Utah, records show 6 consecutive years without a trace of precipitation during August, and 7 consecutive months have occurred with no trace of precipitation.

Weather records in the West contain numerous examples of conditions of excessive precipitation under which full use of the available moisture by the vegetation would be impossible. Table 13 shows some of these heavy rains in comparison with the annual total. In 1938, southern California received a major storm (1). Precipitation had been about normal prior to Feb. 27. Then rain began that, by Mar. 3, had deposited 28.87 inches in the San Gabriel Range. In the flood that resulted, 87 lives were lost, and property damage was placed at 79 million dollars.

Snowfall has direct bearing on the production of livestock in about the northern two-thirds of the western range. Cattle and sheep losses from freezing and from starvation when feed is covered, especially by crusted snow, are of great importance. The need for supplemental winter feeds is greatly increased by snowfall, therefore economic returns in a given year may be determined by snow. Average annual snowfall in inches for various range areas are 55.4 in Denver, 19.8 in Boise, 54.2 in Helena, 9.2 in Albuquerque, 20.6 in Amarillo, 54.6 in Salt Lake City, and 56.6 in Cheyenne.

TABLE 13. AVERAGE ANNUAL PRECIPITATION COMPARED TO MAXIMUM RECEIVED DURING SHORT PERIODS OF TIME FOR SELECTED WESTERN STATIONS (12, 13)

Station	No. days	Year	Precipitation, inches	Annual average precipitation, inches	Ratio, per cent
Phoenix, Ariz.	1	1946	1.27	7.72	16.4
Phoenix, Ariz.	2	1946	2.30	7.72	29.7
Tucson, Ariz.	1	1943	2.51	11.50	21.7
Los Angeles, Calif.	1	1933	7.36	15.24	48.3
Los Angeles, Calif.	2	1933	10.08	15.24	66.1
Pueblo, Colo.	1	1946	2.31	11.67	19.8
Valentine, Neb.	1	1949	3.66	18.34	19.9
Del Rio, Tex.	1	1944	4.95	19.90	24.9
San Antonio, Tex.	1	1951	6.18	27.18	22.7
Modena, Utah	1	1943	1.93	10.14	19.0
Modena, Utah	4	1943	3.14	10.14	31.0
Lander, Wyo.	1	1951	1.95	12.63	15.4

Extreme deviation from these averages on the winter range occasionally occurs with disastrous results. The winter of 1948–1949 was an example of this (Table 14). During that year the sensational "aerial haylift" was operated, in which tons of hay and concentrates were dropped

TABLE 14. MONTHLY AVERAGE SNOWFALL AND TEMPERATURE IN NEVADA DURING WINTER MONTHS OF 1948–1949 COMPARED TO NORMALS (12)

Month	Snowfall, inches	Temperature, degrees Fahrenheit
December, 1948	11.4	27.9
December average	6.1	31.5
January, 1949	19.7	15.0
January average	9.0	29.6
February, 1949	11.0	26.9
February average	7.5	31.0

from airplanes in emergency feeding operations. Locally, snow accumulated because of record low temperatures to 4 to 10 times normal. At Elko, Nev., daily mean temperature was below zero on 6 of the 31 days of January to give an average for the month of 4.7°F., a departure of −18.6° from normal. A low of −38°F was set. It has been estimated that despite costly feeding by both air and ground crews, livestock losses reached 25 per cent and their value reached 2½ million dollars (12).

Decreased lamb and calf production due to emaciation of the remaining animals might be added to this cost.

WATER LOSS TO THE ATMOSPHERE

The low precipitation of the West is made the more serious by high evaporation. Clear, hot days coupled with high winds cause a potential evaporation far in excess of precipitation. This high evaporation reduces soil moisture and increases water loss from plants, necessitating a greater amount of water if the plant is to function normally.

Humidity. Humidity is an important factor determining the effectiveness of moisture for plant growth. When the atmosphere is humid, a greater plant growth can be expected from a unit of precipitation than when the atmosphere is dry. Humidity, in the West, is generally low. The intermountain region and, especially, the Southwest have the lowest relative-humidity averages in the United States. Frequently, the minimum humidity falls below 30 per cent, as contrasted with average minimums of 60 and 70 per cent in the eastern states. In midsummer, humidity minimums of 10 to 20 per cent are common in the West.

Evaporation. Evaporation determines to a large measure the effectiveness of precipitation. Evaporation data are remarkably few, but it is known that the West has a high degree of water loss, especially in the Great Plains and the Southwest. Increases in evaporation rate are from north to south. Long-time data (8) showing evaporation during the 6-month period of April to September, by rough average of two to five weather stations for each state, indicate 32.1 inches for North Dakota, 37.8 for South Dakota, 41.0 for Nebraska, 47.5 for Oklahoma, and 52.4 for Texas.

The Southwest has a high evaporation rate because of high temperature and low humidity. In 1948, Bartlett Dam, Ariz., had an evaporation rate of 133 inches. Totals of 16 to 20 inches in each of the summer months are common in this area. Texas, Nevada, New Mexico, Arizona, and California all have stations which repeatedly report annual evaporation rates of over 100 inches (13).

In the intermountain area, annual evaporation in excess of 60 inches is common, and the monthly evaporation frequently exceeds 10 inches during June, July, and August, the three months having the lowest precipitation and, hence, the greatest need for water.

Precipitation to Evaporation Ratio. The relationship between precipitation and evaporation is so important that ecologists have adopted the precipitation to evaporation ratio as an index to water stress. Weaver and Clements (14) rank areas with a ratio below 0.20 as deserts, those between 0.20 and 0.60 as potential dry grasslands, those between 0.60 and

0.80 to 0.85 as true prairie, and those in excess of 1.00 as capable of supporting continuous forest.

The West has a precipitation to evaporation ratio far below that of the middle western and eastern states, most stations being significantly below the 0.20 limit ascribed to true deserts (Table 15).

TABLE 15. EVAPORATION AND PRECIPITATION RECORDS FOR SOME WESTERN WEATHER STATIONS AND THEIR PRECIPITATION TO EVAPORATION RATIOS
Data from U.S. Weather Bureau (9)

Station	Period involved	Precipitation, inches	Evaporation, inches	Precipitation to evaporation ratio
Lees Ferry, Ariz.	Long-time	4.89	88.39	0.055
Mesa, Ariz.	Long-time	7.11	79.66	0.089
Tucson, Ariz.	1930 only	12.27	86.53	0.142
Yuma, Ariz.	1924 only	0.51	133.41	0.004
Yuma, Ariz.	Long-time	4.34	110.26	0.039
Chula Vista, Calif.	Long-time	10.11	61.77	0.164
Oakdale, Calif.	Long-time	12.54	81.92	0.153
Fort Collins, Colo.	Long-time	15.06	43.49	0.346
Boulder City, Nev.	1938 only	5.63	120.16	0.047
Elephant Butte Dam, N.M.	1930 only	8.82	84.56	0.104
Las Cruces, N.M.	Long-time	8.48	86.43	0.098
Los Griegoes, N.M.	1927 only	5.86	80.15	0.073
Santa Fe, N.M.	1930 only	13.24	64.01	0.207
Austin, Tex.	1930 only	35.74	60.34	0.592

TEMPERATURE

Of the climatic factors, temperature probably is secondary only to precipitation and evaporation in its influence upon vegetation. The range of temperature in the West is great, though it is less variable from year to year than is precipitation.

Temperature belts are closely correlated with latitude but are influenced markedly by the western mountain ranges and the Pacific Ocean. Low-temperature belts extend far south along mountain ranges. Similarly, warm belts extend far north along the Pacific coast and far inland along the Colorado and Columbia Rivers. Altitudinal differences introduce marked differences in temperature within short distances. Four weather stations in Utah at altitudes of 5,575, 7,400, 8,700, and 10,200 ft., have mean July temperatures of 69.5, 65.8, 60.4, and 55.5°F, respectively. Their mean maximum temperatures for July are 85.6, 80.7, 73.0, and 64.5°F., respectively, or a decrease of 1° for every 220-ft. increase in

altitude. The normal expectation is an average annual temperature decrease of about 3.3°F per 1,000-ft. elevation increase (7). Because the West is highly variable in altitude, the temperature may vary greatly within short distances.

North Dakota and Montana are the coldest portions of the western range, with the possible exception of the high mountains. Temperatures of 30 or 40°F below zero are not at all uncommon in these areas, and extremes of 60°F. below zero have been recorded. The extreme Southwest and Pacific Coast may be virtually frost-free during the entire year.

The eastern limits of the plains, especially to the south, exhibit high summer temperatures. Likewise the Southwest, especially along the lower Colorado River, is extremely hot. Average daily maximum temperatures for July fall between 110 and 120°F. for some parts of Death Valley, and temperatures of over 130°F. have been recorded. This high temperature belt extends through the entire central valley of California.

Frost-free Period. The distribution and growth habits of native plants are influenced greatly by duration of the growing season. A plant must either be resistant to frost or need but a very short period for maturing its seed if it is to live in areas such as the higher mountains of the West, where the frost-free period may be less than 2 months.

The West, except the Pacific Coast and the extreme southern portion, has a short growing season, with the last killing frost generally occurring at lower elevations during May and at higher elevations after June 1 (8). The first killing frost in the fall may occur in September. Vast areas in the high mountains have a safe growing season of less than 90 days, though local areas may be subject to frost at any time. The Pacific Coast and southern areas at lower elevations have a frost-free period of over 240 days.

WIND VELOCITY

Average wind velocities are high in the Great Plains, where topographic barriers are at a minimum. Northern Texas and North Dakota are regions of maximum blowing. Also, Nevada is the center of a high wind-velocity area, which extends north and east far into Idaho. Minimum wind-velocity areas center in southern Arizona and California, in northern Utah and western Wyoming, and in Oregon and Washington. Wind velocities are not of major importance in influencing vegetation development, but, in association with extremes of temperature, effects may be severe. Hot winds sometimes sweep across the plains, generally from the south; and they sear vegetation rapidly, reducing soil moisture at the same time. During cold periods of the year, blizzards may cause winter kill of vegetation.

THE EFFECT OF CLIMATIC FACTORS UPON LIVESTOCK

Not only do climatic conditions determine the amount and character of vegetation available to livestock grazing, but they have direct influences as well. Warm and wet climates are conducive to livestock parasites and diseases. Aridity and cool temperatures are factors in limiting the spread of disease among livestock. Warm Chinook winds, and even cold winds, may serve a useful purpose in removing snow and thus exposing forage to livestock during the winter months. Conversely, cold temperatures associated with blizzards, especially if accompanied by heavy precipitation, may freeze livestock. Unseasonally wet weather, particularly if it occurs during lambing or calving periods, may have serious consequences. Cold and snowy winters make use of supplemental feeds necessary. Annual variation in these requirements cannot be forecast, hence wise stockmen in northern climates are prepared each winter to feed for extended periods.

Animal production is closely correlated to weather. Generally, wet years result in plentiful feed and good gains. Dry years may cause tremendous production decreases unless costly supplemental feeds are resorted to.

SOILS OF THE WESTERN UNITED STATES

Soil is a product of the action of climate and biological complexes upon rock material. Since the possible combinations are almost infinite, the number of distinct soils is very great. Some differ in major respects, others merely in slight physical or chemical characteristics. Some soil types have matured through weathering to attain definite horizontal structure. Others, because of newness, repeated disturbance, or slow weathering processes, show almost no structural characteristics.

The type of soil on a range is of importance not only to the kind and abundance of forage produced but, likewise, to the type of management that is possible on the range. Not only do the physical and chemical characteristics of a soil determine the ability of the soil to furnish plant nutriment, but they also determine the rate and depth of water penetration and the availability of this water to plants. Soils with an impervious surface absorb very little moisture, and soils that are coarse-textured may dry to depths below the feeding zone of grass roots In these cases, precipitation has a very low efficiency. A well-developed soil will absorb water readily and store it within reach of the plant roots, thus making precipitation highly effective. Certain soil types, because of rapid percolation or greater stability, are all but immune from erosion. Others are so erosive as to make grazing, even under careful control, hazardous. Some

soils are so fertile as to make the likelihood of successful artificial seeding very good, whereas others are so sterile as to make successful seeding virtually impossible. A range manager always should become familiar with the soil of the area with which he deals.

Since the western climate is variable and the terrain irregular, soil is extremely heterogeneous. Some mountainous areas receive high precipitation, produce luxuriant vegetation, become highly stable, and produce deep, black soils, occasionally acid in reaction. Some valley areas have poor drainage because of topographic characteristics; and, through constant leaching from adjacent hillsides, the soil becomes saline, and sometimes alkaline, to the virtual exclusion of plant life. The slowness of climatic action, the steep slopes, or the newness of some areas results in soils that are extremely rocky and, often, but a few inches deep. This variation is confusing and makes soil interpretation difficult for one not schooled in the science. Such complexity, however, makes a knowledge of range soils the more important to a comprehensive analysis of range problems.

Knowledge of the major soil groups of the West (Fig. 9) gives a better understanding of vegetation groupings and regional range problems. The following soil-group descriptions give only a superficial picture of western soils, for each soil is highly variable and many are inadequately described (10).

Gray-brown Podsolic Soils. The gray-brown podsols are limited in area and are of little importance as range land. They occur, in the West, only along the coast from central California northward and in the forested lands of northern Idaho and northwestern Montana. Similar types occur locally under coniferous forests throughout the West. They are formed under heavy precipitation and continued leaching. This soil group is typical of deciduous forests in the East. They are usually slightly acid in reaction and coarse in texture. The brown surface layer, high in organic matter, is shallow and is underlain by a light-colored, usually gray, subsoil. The soil is usually easily eroded and generally unsuited to cultivation. Production of timber is probably its best use.

Prairie Soils. The prairie soils develop under grass in the moderately humid and cool climate of the Middle West. Small areas of prairie soil, however, have developed in California and the Palouse region of eastern Washington and Oregon. The prairie soil group is dark brown to black and may be slightly acid, having no lime zone. These soils are highly productive, being deep and fertile.

The prairie soils of the Palouse region are almost entirely cultivated. Because of this, they have little importance as range soils, though, originally, they supported excellent stands of wheatgrasses of high grazing capacity. The prairie soils of California are found on rolling hills to eleva-

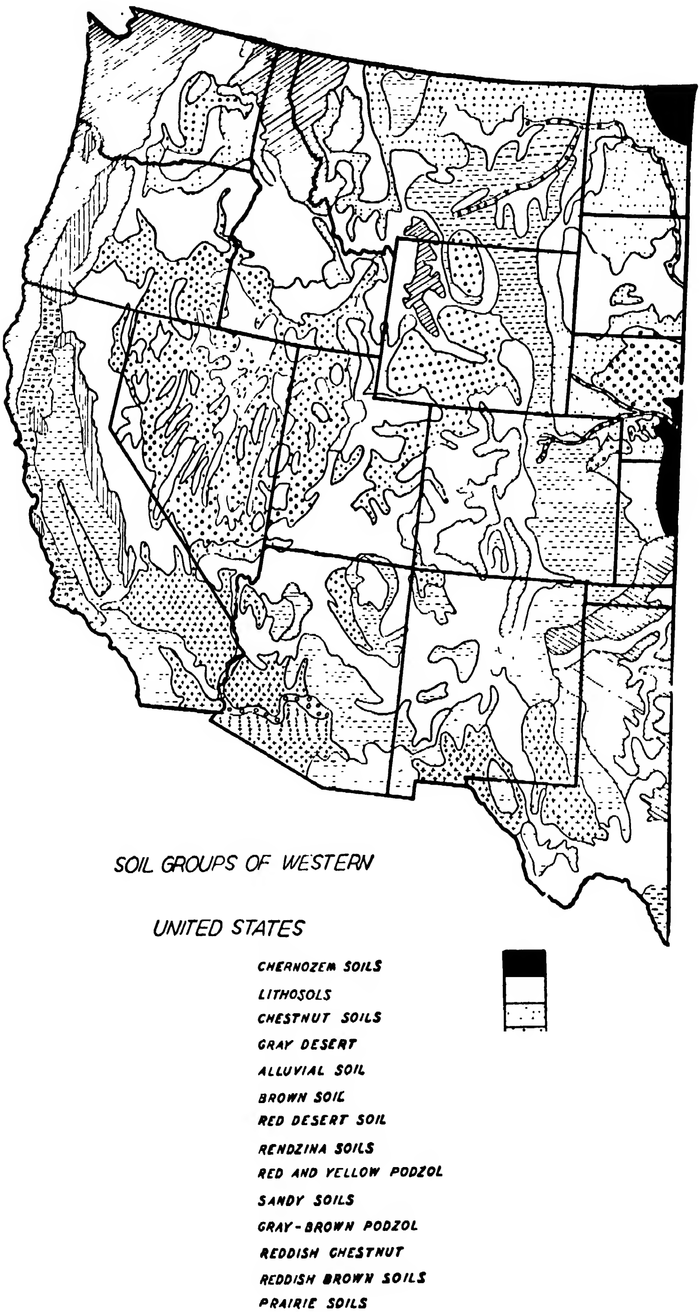

FIG. 9. Major soil groups of western United States. [*After U.S. Bureau of Soils* (10).]

tions of 4,000 ft. Originally the vegetation was mostly grass with a few *small live-oak trees. This region remains largely uncultivated and is important as livestock range. These soils are generally erosive beca.. e of the topography and must be carefully managed.*

Chernozem Soils. The chernozems, or true grassland soils, are deep and fertile, being characterized by a dark-brown or black surface, usually dark subsoils, but always with a layer of lime concentration. They are typical of the middle-western corn belt, though small areas also occur in eastern Washington and Oregon. The topography is rolling and the climate subhumid.

The chernozems are almost all farmed. Although they formerly supported excellent range, they are now of little or no importance to the range industry. Their best use is grain production, chiefly wheat and corn.

Chestnut Soils. The chestnut soil group occupies large areas of the less humid Great Pl· · and northern intermountain region. They are typically dark brown or gray-brown on the surface and are underlain by a calcareous layer. Production on the chestnut soils is limited by deficient precipitation, but large areas are cultivated, small grains being the major crop.

The chestnut soils occur in the Great Plains in the northern half only, especially in Montana and the Dakotas, and extend as far south as Central Kansas. The area, generally, is used for dry-land wheat. In the arid or rocky areas, the native short grass vegetation is used for grazing largely by cattle. Under careful management, excellent production is possible on such ranges.

In the intermountain region, also, the chestnut soils are confined to the northern parts, being found only in narrow strips along the bases of mountains. Here, topography frequently is such as to prohibit cultivation, though the more level areas, especially with irrigation, produce excellent crops. The uncultivated lands produce sagebrush and bunch grass and are of only intermediate productivity as range land.

Red and Yellow Podsolic Soils. The red and yellow podsols are, typically, southeastern soils; however, extensive areas occur in western Oregon and central California. These soils are strongly leached clays, generally red throughout, and acid in reaction. Open pine and live oak are the native cover of most of the western red podsols, though much of the land has been broken for crop production. The land is highly productive and, where topography permits, generally is cultivated, producing specialized crops such as fruit. The unplowed land is devoted to timber production, and grazing is of but secondary importance.

Reddish Chestnut Soils. The reddish chestnut soils are found only in northern Texas, western Oklahoma, and southwestern Kansas, in a warm semiarid climate. These soils, typically, are a dark reddish brown at the

surface and become light red to gray in the calcareous subsoils. They are fertile, but high evaporation and low precipitation prohibit extensive cultivated crop production, though cotton and wheat are grown satisfactorily in some localities. The vegetation, generally, is mixed grass with an occasional stand of small trees, usually oaks. These lands, especially the rough broken and drier areas, are used extensively for cattle producton and are excellent range.

Brown Soils. The brown soils occupy a large area in the farthest western and most arid portion of the Great Plains and a few small spots in the northern intermountain region. The climate is semiarid, and the vegetation is grass. The soils are brown on the surface and light brown to gray or white at depths of 1 to 2 ft. The subsoils are calcareous. The brown soils are subject to wind erosion, especially in the southern Great Plains area. The prevailing cropping system, wheat alternating with fallow, is conducive to erosion; and much damage has been done. Generally, precipitation is too low for intensive cultivation; hence, much of the area has remained in native cover. Under careful management, it is productive range land, especially for cattle.

Reddish-brown Soils. The reddish-brown soil group is confined to southern Arizona, New Mexico, and Texas. The climate is hot and semiarid, with high evaporation. The soils are red to reddish-brown at the surface and pink or white in the very calcareous subsoils. The soils are fertile, and under irrigation the area is highly productive.

The native vegetation is desert grass overlain by shrubs or small trees. Grazing capacity is fair, but only by careful management can it be maintained at its maximum production. Cattle are the predominant stock, though sheep are locally important.

Noncalcic Brown Soils. The noncalcic brown soils occur in southern Arizona and central California, in hills or intermountain valleys. The climate is warm and semiarid, producing shrubs or small trees underlain by a sometimes excellent grass cover.

The soil is brown to red at the surface and red below. It commonly is devoid of lime but is neutral in reaction. Though highly productive under irrigation, most of the area is suitable to grazing only. Excellent grazing can be obtained from these lands if they are managed carefully. Lack of water is a problem in some localities. Cattle and sheep are both important.

Gray Desert Soils. The gray desert soils are found scattered through the eastern intermountain area and in California's central valley. The climate is intermediate in temperature and arid, precipitation in some areas not exceeding 3 to 5 inches per year. The surface soils are gray or very light brown because of low organic content. The subsoils are gray and high in lime content. Since the climate is dry, soluble salts are abundant. Though these soils are locally productive under irrigation, they generally

are uncultivated. The vegetation is semidesert shrub, chiefly *Atriplex*, and grasses are sparse.

As range land, the gray deserts are low-producing, being used mainly as winter sheep range. They are highly erosive, and damage from both water and wind is common.

Red Desert Soils. The red desert group occurs in southern New Mexico, Arizona, and California where the climate is hot and dry. The soils are red to pink at the surface and pink to white at the lower layers Lime and soluble salts are abundant because of the low precipitation and absence of leaching. Cultivation is possible only with irrigation, and farming is rare.

The native vegetation is desert shrub, and in its present condition the area is not highly productive as grazing land. Yearlong grazing of cattle and sheep is the common practice.

Rendzina Soils. The rendzina soils are dark gray or black on the surface and gray to white the calcareous sublayers. They have not developed a deep organic layer. They reach their greatest development in central Texas and occur in small areas in southern California and northwestern Arizona. The climate is hot and semiarid, making crop production hazardous. The vegetation is largely small trees or brush, with grass undergrowth.

Cultivation is common on the California rendzinas but is rare in Arizona. The majority of the area is devoted to livestock production, both sheep and cattle grazing being common.

Lithosols and Shallow Soils. The lithosols, or rocky soils, and the shallow soils of the arid region have no profile development, generally, because of their newness and because of the slow development in arid climates. In many places the parent material, or bedrock, is exposed. The soils of this group are extremely heterogeneous, their only universal relationship being poor development. The arid lithosols occupy vast areas through the western mountain and intermountain regions from southern New Mexico to Canada and from California to the Great Plains. Large areas occur also in the Black Hills region in western South Dakota and in central Texas.

The soils are shallow and stony and vary in depth from almost no true soil to several feet. Their color varies from light gray to brown or red and even to black. Generally they are erosive and low in productivity.

The climate is variable, being hot in the desert and cold in the mountainous regions. Precipitation is low on dry foothills but reaches 40 inches per year on high mountains.

The vegetation of the lithosols varies greatly. Vast lava beds, rock outcrops, and steep topography produce almost no vegetation. Typically, however, there is a sparse cover of coniferous trees, usually junipers and pines. Sagebrush and grass are common in some localities.

The lithosols are nonarable because of their shallow and rocky characteristics. They are therefore important as range land and somewhat so for timber production. As grazing land, this area is productive in the mountains, where high rainfall results in good forage; but the foothill and desert lands are low-producing. In the mountain and intermountain regions of the West, sheep and cattle are raised in great numbers, and both are important. The Edwards Plateau region in Texas produces about 70 per cent of the goats grown in the United States (5).

Alluvial Soils. Alluvial, or stream-laid, soils are not abundant in the West; but some occur in the central valley of California and, locally, along major rivers and gently sloping fans. The soils are dark and high in organic material. Locally, salinity is a problem. Because most of these alluvial soils can be irrigated, cultivated-crop production is common despite the aridity of the climate. Generally, the uncultivated areas are not highly productive as range land; hence, the alluvial soils are not important in range management.

Sandy Soils. Dry sandy soils are locally important in the West, especially in north central Nebraska. This region is characterized by rolling sand hills most of which are grassed and, hence, relatively stable. Occasional blowouts, however, remind landowners that the area must be carefully handled.

The soil is fine, loose, sand with but little development and is leached of lime. Cultivation is generally inadvisable, and the area is used primarily for livestock, especially for summer grazing. The Nebraska sand hills are among the best range lands in America and have generally been managed well. Tall grasses grow abundantly and furnish excellent forage.

Local areas in Texas, New Mexico, and Oregon are composed of shifting sand and support little or no vegetation. Only in local protected areas can such land be used even for livestock grazing.

INFLUENCE OF PHYSICAL CONDITIONS UPON VEGETATION AND MANAGEMENT

The effect of varied conditions of soil and climate is to produce varied vegetation types, each adjusted to the conditions under which it must grow. Because of these many conditions, management practices must be varied according to the potential of the habitat.

Not only do soil differences cause differences in natural vegetation, but climatic variations from place to place and from year to year cause great variety and constant fluctuation in amount and kind of plants produced. Necessarily, then, the range manager must be alert to the infinite variation in conditions encountered upon the range, and he must plan his operations according to the restrictions imposed by nature.

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CHAPTER 3

GRAZING REGIONS OF THE UNITED STATES

The numerous combinations of factors affecting vegetation in the West have resulted in correspondingly numerous vegetation combinations. A vegetation cover has developed that is typical of each set of conditions. Further complication arises from the activities of man and livestock, which have altered materially the normal vegetation. Grazing, cultivation, timber cutting, control of fire, and damming and diverting of water have been most important in effecting changes that have qualitatively or quantitatively changed fully 90 per cent of range vegetation.

Several classifications of the native vegetation have been made by ecologists that in part are applicable to range usage. In some cases, however, it is desirable to deviate from the usual classifications and delimit vegetation largely according to grazing value.

The terms *grazing type* or *vegetation type* are not distinct in their usage. They generally refer to the species or various combinations of species which dominate or *appear to dominate* the range, thus giving it characteristic appearance. The term *vegetation region* applies to broad geographical areas of vegetation, parts of which may be dominated by several different species. The vegetation regions are large areas having comparable vegetation, climate, and range practices. Each may be composed of a number of grazing types (see Chap. 7, page 165).

Nine great regions of vegetation are recognized in western United States that are analogous as to plant composition or range value. There is no sharp boundary line between many of these regions, and there is justification for further separation in many instances. These nine are as follows: (*a*) tall grass, (*b*) short grass, (*c*) desert grass, (*d*) bunch grass, (*e*) northern or intermountain shrub, (*f*) southern desert shrub, (*g*) chaparral, (*h*) piñon–juniper, and (*i*) coniferous forest. The approximate location of these types is shown in Fig. 10, though an exact delimitation is impossible. These regions were mapped according to original conditions so far as possible, though many theories as to former vegetation had to be disregarded because of the lack of definite knowledge.

THE TALL-GRASS REGION

Unfortunately for the range industry the great tall-grass region of the Middle West proved to be so valuable for cultivation that it is now plowed

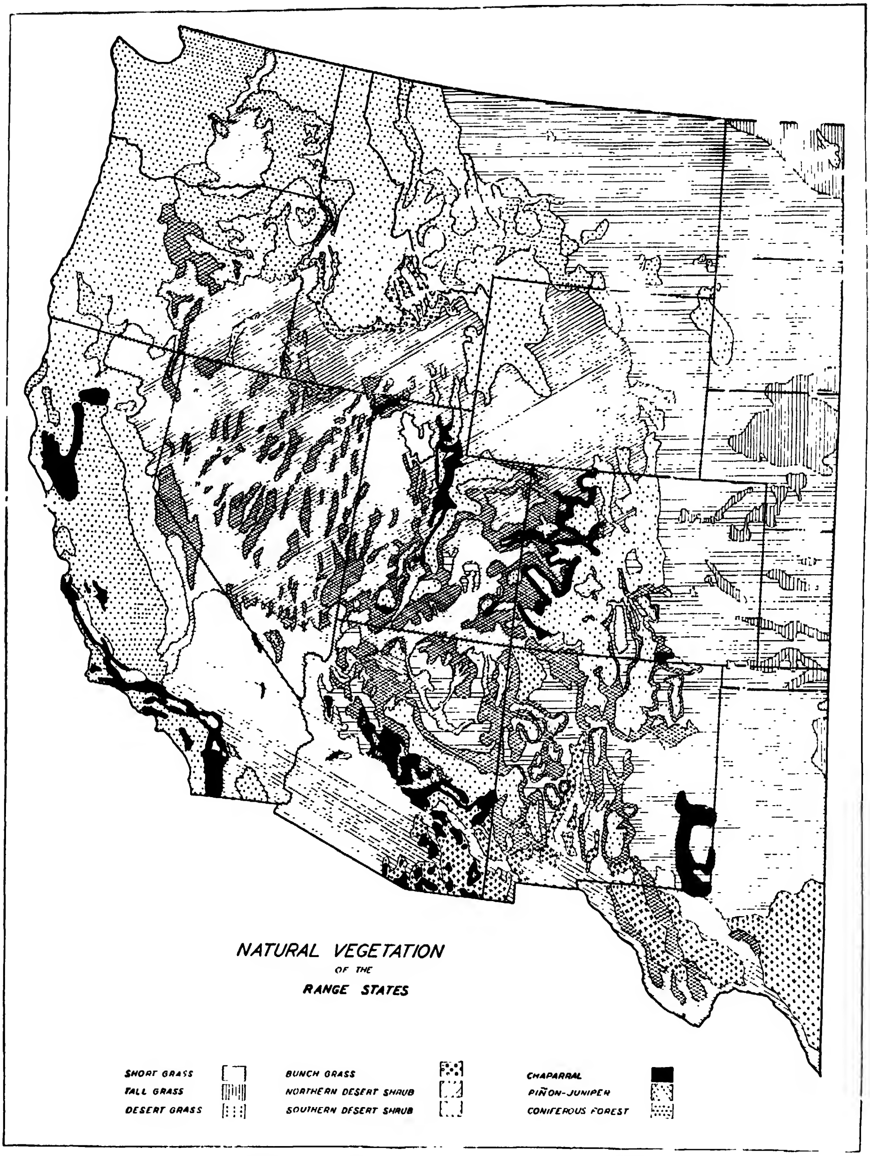

FIG. 10. Natural vegetation regions of the range states.

almost in its entirety (Fig. 11). Only the most xeric portions and those parts underlain by a soil too rocky to admit the plow remain. The tall-grass prairie lies immediately west of the eastern forests. Originally, it occupied a strip from Canada to Mexico and was 150 to 500 miles wide.

Physical Conditions. Annual precipitation in the tall-grass prairie varies from about 25 to 38 inches. The eastern portions receive higher precipitation than do the western. Likewise, because of higher evaporation, the southern parts are more arid than the northern. Annual evaporation is about 70 to 80 inches in Texas in contrast to 40 to 50 inches in North Dakota.

High temperatures and heavy winds are common. Growth begins early in spring, especially in the southern parts; but summer precipitation is abundant, and plants continue growth throughout the summer, providing green forage until late fall. The growing season varies from 4 to 9 months.

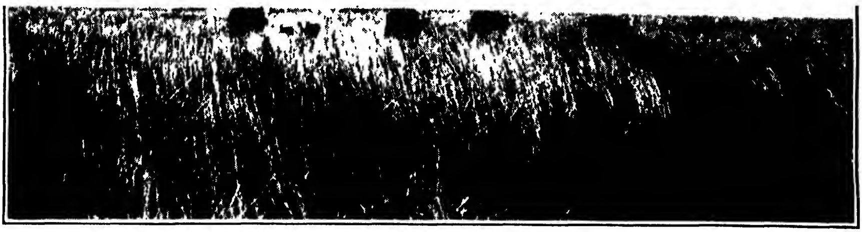

FIG. 11. Tall-grass prairie in Oklahoma dominated by *Andropogon gerardi* and *Andropogon scoparius*. This range has grazed cattle at the rate of 4 to 8 acres per animal-year for decades.

The prairie is practically level; hence, cultivation is almost universal. The soils are deep, dark in color, and fertile. Some of the best cultivated pastures in the world are to be found within this area.

Natural Vegetation. Although many combinations of vegetation occur, by far the most important dominants are two species of the genus *Andropogon*, little bluestem (*A. scoparius*) and big bluestem (*A. gerardi*). The former is most abundant on uplands and the latter on lowlands. Together these two constitute about 72 per cent of the vegetation on grazed climax prairie (28).

Grass types dominated by *Andropogon scoparius* probably exceed all other upland types combined (Fig. 12). Early growth, together with vigorous tillering and abundant root growth, account for its dominance. Uniform appearance, despite large numbers of flowering forbs, is usual in

the prairie because the dominating grasses reach heights of 5 to 6 ft., thus overshadowing associated plants.

Important associations of needlegrass (*Stipa spartea*) and dropseed (*Sporobolus heterolepis*) occur on uplands especially on shallow, rocky or sandy soils, and sloughgrass (*Spartina pectinata*) on bottomlands. The latter may reach heights of 6 to 10 ft. and form a foliage density of almost 100 per cent.

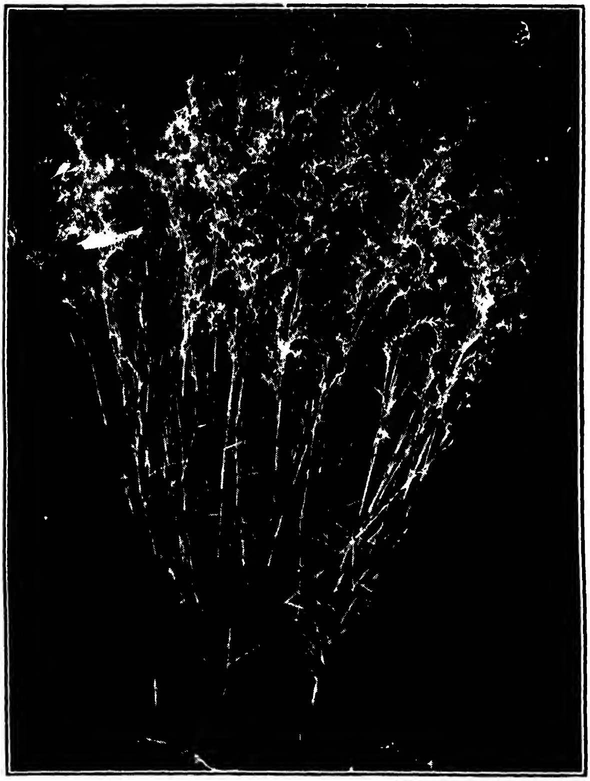

FIG. 12. Little bluestem (*Andropogon scoparius*), the chief dominant of upland prairie ranges. (*Photograph by J. E. Weaver.*)

In the vast and important sand-hills range area of northwestern Nebraska *Calamovilfa longifolia* is the dominant species, and *Bouteloua hirsuta*, *Sporobolus cryptandrus*, and *Muhlenbergia pungens* are important associates (10).

In the southern parts of the tall-grass prairie, important dominants are *Andropogon glomeratus*, *Andropogon ternarius*, *Erianthus*, *Elyonorus*, *Heteropogon*, *Trachypogon*, and *Paspalum* (25).

From Texas into Canada, extensive areas of drier prairie are dominated by mid-grasses. These include *Agropyron smithii*, *Bouteloua curtipendula*,

Panicum virgatum, Sporobolus cryptandrus, Aristida spp., and *Stipa* spp. (8, 12). These grasses dominate favorable sites as far west as the Rocky Mountains but some have decreased with drought and grazing. They also dominate unfavorable sites throughout the tall-grass prairie, extending their dominance greatly during drought. The tall-grass region was subjected to frequent drought from 1934 to 1941. In pastures, little bluestem, Kentucky bluegrass, and many other grasses decreased in density as much as 80 to 95 per cent (26). *Sporobolus cryptandrus* increased to a position of major importance, and from South Dakota to Kansas it became a dominant over thousands of acres. *Agropyron smithii* likewise increased rapidly. By 1945 parts of the prairie were 70 per cent short grasses, the remainder being largely weeds (1).

Reaction of the Tall Grass to Grazing. Heavy grazing on tall-grass vegetation may greatly change the composition. Though grasses form 97 per cent of the normal composition, they may be reduced to less than 20 per cent, with an accompanying reduction in yield from 3,000 lb. per acre to less than 300 lb. Well-managed grazing seems to cause but little change (26), and deteriorated ranges will recover rapidly upon protection (27). Light overgrazing causes the invasion of Kentucky bluegrass (*Poa pratensis*), blue grama (*Bouteloua gracilis*), and buffalo grass (*Buchloë dactyloides*), and continued use results in an increase in low-value weeds. In north Texas, *Stipa leucotricha* and *Andropogon saccharoides* are prominent in overgrazed prairies (9); and, especially in Oklahoma, sand sage (*Artemisia filifolia*) is abundant on sandy soils.

Grazing Value of Tall Grass. The tall-grass vegetation does not cure well on the range. Almost all the species leach badly and lose much of their nutritive value upon maturity. During the winter, these grasses are almost worthless; to ensure proper gains, animals must be fed some supplement high in protein. Because of their rankness of growth, the prairie grasses are seldom grazed by sheep; and older cattle, in general, do better than younger animals.

It has been estimated that the original tall-grass range would support one animal unit per month on about 1.9 acres (23).

Studies in the sand hills of western Nebraska (10) showed the following important subtypes and their grazing capacities in surface acres per cow-month:

Dune-sand	Dry valley	Dry meadow	Wet meadow	Saltgrass	Total area
2.13	1.92	0.79	0.53	1.46	1.91

Perhaps the most famed livestock-producing area in the tall-grass region is the Flint Hills range in east central Kansas, where rocky soil

prohibits cultivation. As a cattle range, this area is among the best in America. Here, cows or steers are allowed only 3.5 to 6.5 acres for a 6-month grazing season (2).

THE SHORT-GRASS REGION

The short-grass region, or the Great Plains grassland, is more variable than most grasslands because of its great geographic range. It has been suggested that the short grass is but a grazing subclimax of the mixed-grass prairie (25). It may be considered a climax with native grazing animals preventing the development of a mixed-grass cover (15).

The short-grass region lies immediately east of the foothills of the Rocky Mountains and extends eastward to approximately the 100th meridian, where it gives way to taller grasses. Southward, the true short grass reaches southern New Mexico and central Texas, where it merges with the desert-grass region. Large isolated tracts occur in northern Arizona. Northward it extends far into Canada, though its form in the northern parts is distinctly toward a mid-grass type. The short-grass plains, estimated at 280 million acres, are larger than any western vegetation region and produce about one-third the range beef in the United States. Of the 280 million acres, about 198 million is used as range land.

Physical Conditions. Short grass characterizes a climate in which the precipitation is between 10 and 25 inches, and 70 to 80 per cent is received in the form of rain between April and September (Fig. 130). Most of the moisture, then, comes during the growing season and is immediately available to plants. The light rains do not result in deep percolation, and the leached material, essentially lime, is deposited to form a hardpan. The climax vegetation, therefore, is short-rooted and depends upon surface moisture that falls during the growing season.

Natural Vegetation. The short-grass plains, over vast stretches, are dominated almost exclusively by blue grama (*Bouteloua gracilis*) and, through much of its range, a companion species, buffalo grass (*Buchloë dactyloides*), both of which are very short in stature and form a dense sod of almost velvety appearance (Fig. 13). Blue grama produces 50 to 95 per cent of all forage on well-managed ranges and is the species upon which range management should be based (8). With these dominant grasses occur a variety of less important grasses, forbs, and low shrubs including:

Muhlenbergia torryei	*Aristida longiseta*	*Salsola kali tenuifolia*
Bouteloua hirsuta	*Carex filifolia*	*Artemisia frigida*
Sitanion hystrix	*Astragalus* spp.	*Gutierrezia sarothrae*
Stipa comata	*Oxytropis lambertii*	*Eurotia lanata*
Hilaria jamesii	*Plantago purshii*	*Opuntia* spp.
Agropyron smithii		

Reaction of the Short Grass to Grazing. The grasses reproduce mainly by seed despite exceptions such as the stoloniferous buffalo grass (Fig. 14) and the rhizome-bearing western wheatgrass. Most of the grasses produce flower stalks at almost any time during the summer when rains chance to come.

Despite the tremendously heavy grazing to which the plains have been subjected, they have remained remarkably productive. The native short grasses are outstanding in their resistance to grazing, partly because of their low stature. Upon too-heavy use, the grasses often give way to

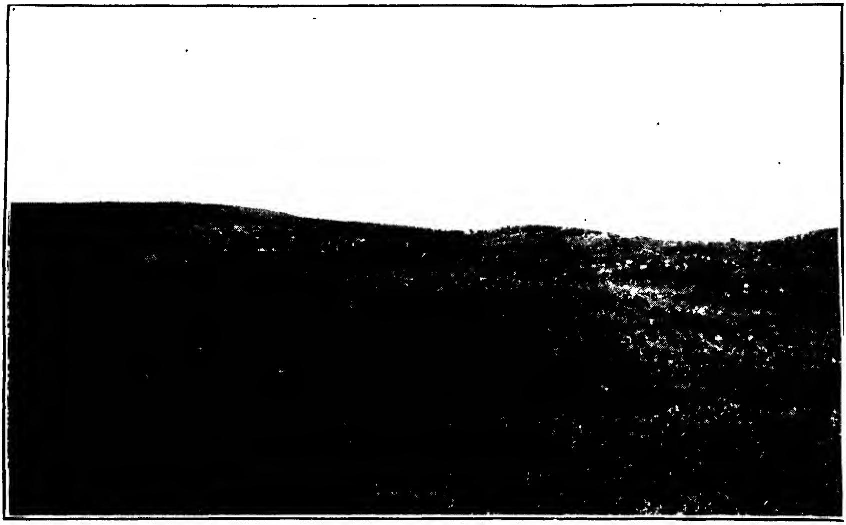

FIG. 13. The short grasses cover thousands of square miles of rolling plains, giving them a uniformly smooth appearance.

weedy plants such as *Opuntia*, *Grindelia*, and *Salsola* and, in the southern parts, to *Yucca* and *Gutierrezia* (Fig. 15).

Unfortunately, dry-land cultivation has been attempted on vast areas of the short-grass plains which are unsuited to cultivation without irrigation. As a result, thousands of acres have been stripped of their natura cover and later abandoned. Such lands produce annual weeds, chiefl Russian thistle, and require many decades to return to normal. In th northern states, especially Montana and the Dakotas, where abandone land is particularly abundant, the seeding of crested wheatgrass (*Agr pyron cristatum*) has given sensational results. In western Kansas a Oklahoma and in eastern Colorado, many of these abandoned lands ha been eroded during drought periods by the prevalent heavy winds.

serious did this appear that for a time considerable pessimism was felt as to the possibility of ever reclaiming these lands.

Grazing Value of the Short Grass. The short-grass plains are noted for their excellent grasses, which are highly nutritious, unusually attractive to animals, and which cure well on the range. Often forage may be in short supply in spring, for many of the species are warm weather plants.

Both the vegetation and the topography of the plains are ideally suited to cattle. The cattle are grazed on the plains yearlong in the southern parts; 8 to 10 months or, with supplemental winterfeed, 12 months in the

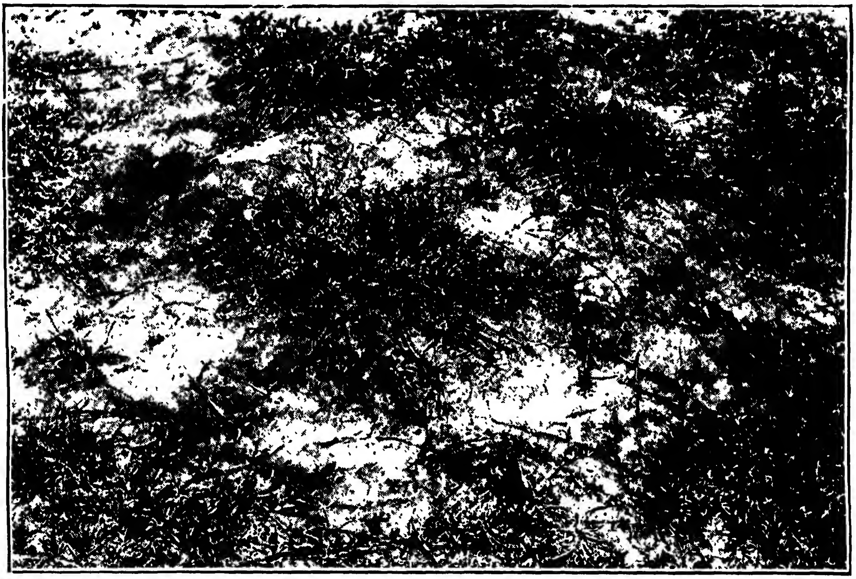

FIG. 14. Buffalo grass (*Buchloë dactyloides*) is strongly stoloniferous as shown by this photograph of a range, badly depleted by drought, upon which the buffalo grass is spreading rapidly. (*Photograph by J. E. Weaver.*)

central parts; and 4 to 8 months in the northern parts. In the central and southern areas, animals sometimes are summered on the high mountains and grazed on the grasslands in the fall, winter, and spring. Vast grassland areas, however, are grazed during the summer, for they furnish the best forage during that period, and animals are wintered on harvested feeds. In the northern areas, animals generally are fed on hay during the long, cold winter and are summered on the grasslands.

THE DESERT-GRASS REGION

The desert-grass region occupies an estimated 93 million acres (23) in the Southwest. Despite its natural aridity, it is a major range region. In

the United States, it is confined largely to the southern portion of New Mexico, Arizona, and Texas below an elevation of 4,000 ft. The largest area is in Texas, centering in the Edwards Plateau. Similar grasslands extend far into Mexico.

Physical Conditions. The desert-grass region is rough in topography, with numerous hills and mesas. It is much the driest of the grasslands, having low precipitation and excessively high evaporation. Most of the area receives between 10 and 20 inches of precipitation, of which 50 to 70 per cent falls during the late summer. Annual evaporation as high as 80 inches is common. Temperatures also are high.

As in the short-grass area, rainfall does not percolate deeply, and vegetation must secure the moisture rapidly or it is lost to evaporation. Fortunately, many of the forage plants cure well and furnish good feed even in the dry state.

Natural Vegetation. The vegetation is highly variable, sometimes being almost pure grass and sometimes grass with an open savanna of desert shrubs forming an overstory. Climatic studies indicate similarity of the desert grasslands to the southern desert-shrub region (22).

Chief among the associated shrubs are mesquite (*Prosopis juliflora*), burroweed (*Aplopappus tenuisectus*), creosotebush (*Larrea divaricata*, soapweed (*Yucca* spp.), shin oak (*Quercus* spp.), catclaw (*Acacia greggii*), snakeweed (*Gutierrezia* spp.), tarbush (*Flourensia cernua*), and

FIG. 15. Snakeweed (*Gutierrezia sarothrae*) has invaded thousands of acres of the short-grass plains upon misuse. This plant is seldom grazed by livestock. See page 55.

cactus (*Opuntia* spp.). Small coniferous trees, mostly juniper, normally dominate rocky hills and washes. On the Edwards Plateau, a growth of dwarf oaks and mesquite in open savanna covers almost the entire area (Fig. 16).

Areas of pure grass are now rare. The grass stand is open in the arid western sections; in the less arid eastern sections, it becomes very dense and highly productive. Probably the most important single species, certainly in the western portions, is black grama (*Bouteloua eriopoda*), one of the finest grazing plants in the Southwest (Fig. 17). Its high preference value, vigor of growth, nutritiousness, and ability to cure and form valuable dry-season forage make it unsurpassed in the desert region. Second to black grama probably is curly mesquitegrass (*Hilaria belangeri*), which dominates vast areas, especially in more easterly portions. Other

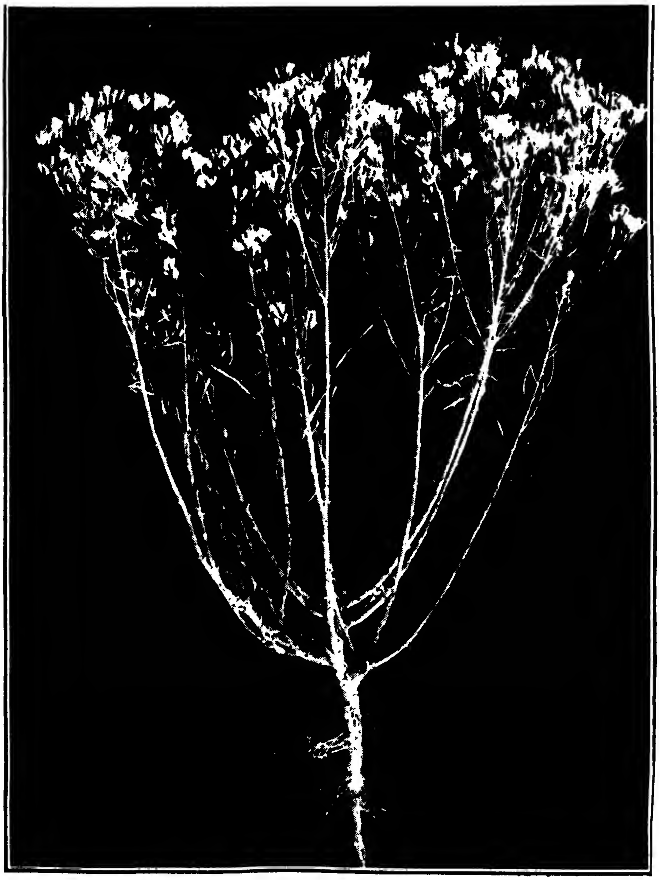

FIG. 15. (*Continued*)

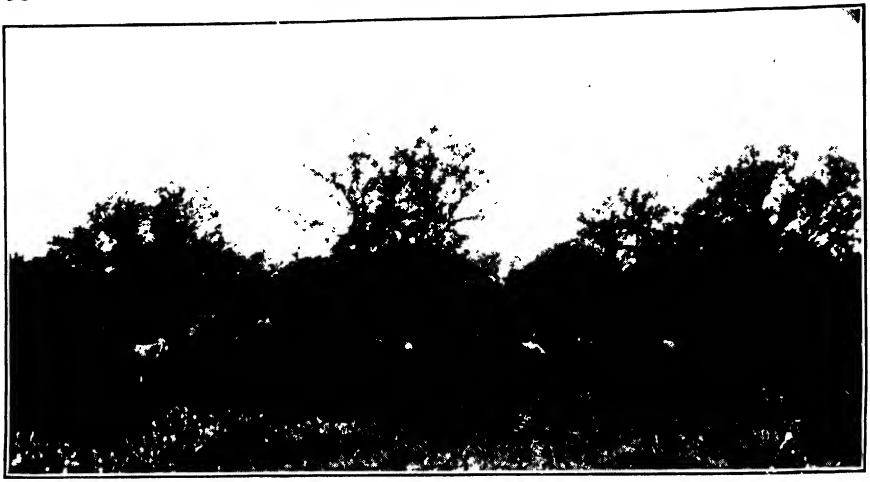

FIG. 16. An oak and mesquite savanna over desert grasslands on the Edwards Plateau, Texas. Grasses are largely *Hilaria belangeri* and *Buchloë dactyloides*. Goats, sheep, cattle, and deer graze on this range together.

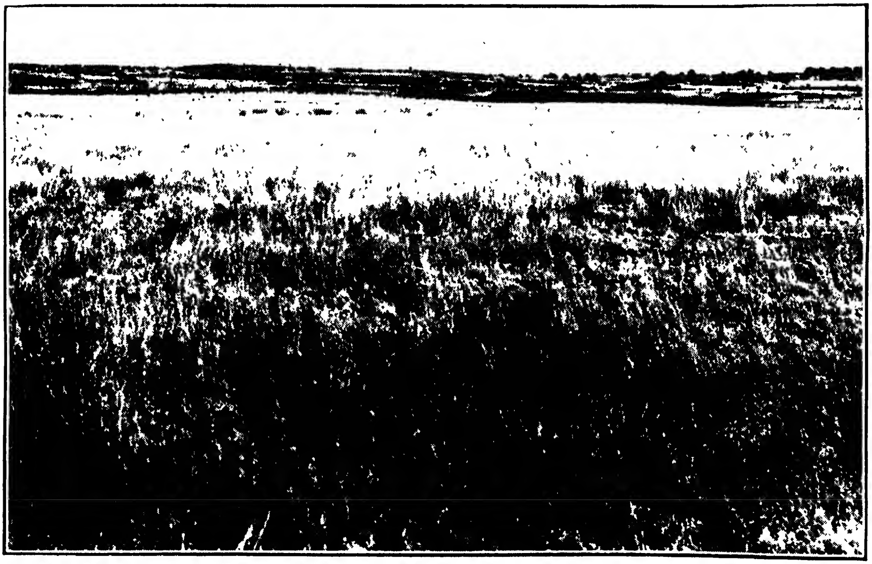

FIG. 17. Dense stands of black grama (*Bouteloua eriopoda*) dominate low plains in the Southwest where blue grama (*Bouteloua gracilis*) dominates higher tablelands and benchlands.

desert-grass species of importance are tobosagrass (*Hilaria mutica*), three-awn grasses (*Aristida longiseta*, *A. divaricata*, *A. purpurea*), blue grama, hairy grama (*Bouteloua hirsuta*), Rothrock grama (*Bouteloua rothrockii*), buffalo grass (*Buchloë dactyloides*), sand dropseed (*Sporobolus cryptandrus*), and, originally very important, bush muhly (*Muhlenbergia porteri*).

Reaction of the Desert Grass to Grazing. Heavy grazing tends to increase the shrub growth at the expense of perennial grasses. Worthless shrubs such as *Gutierrezia sarothrae* and *Aplopappus tenuisectus* invade the desert grasslands, upon destruction of the grass, until they become the dominant species (Fig. 43). Cholla cactus (*Opuntia* spp.), rubberweed (*Actinea* spp.), and jimmyweed (*Aplopappus heterophyllus*) have increased tremendously. Likewise, many annual grasses, chiefly species of *Bouteloua* and *Aristida*, have become abundant. Rapid spreading of the low-value mesquite, which collects shifting sand to form the familiar mesquite sand dunes, is also serious.

FIG. 18. Desert grassland range in southern Arizona dominated by *Bouteloua eriopoda*, *Tridens pulchellus*, and *Bouteloua rothrockii*. Despite 18 years of protection, note mesquite invading.

Many investigators consider that fire control by man has been a factor in increasing shrub growth in the desert grasslands (13). According to this concept, the open grassland is really a subclimax to a true climax of low-growing trees and shrubs underlain by grasses. Substantiating this theory, shrubs, especially mesquite, have been shown to increase rapidly even when the range is completely protected from grazing, when fire is prevented.

Grazing Value of the Desert Grass. The desert-grass region is valuable as a livestock range despite the aridity of the climate (Fig. 18). Most of the grasses are highly preferred and nutritious; fortunately, they cure well on the ground and thus furnish feed through most of the year despite

a short growing season. The range is used practically all year long. Sheep do well on these dry grasses; but, fundamentally, they constitute a cattle range, and sheep are in the minority. Often, scattered browse plants add to the value of the range. Many are too thorny for ready consumption, but most are utilized to some extent.

Certain areas of the desert grasslands originally were of high grazing value and seem to have remained near their original productivity. Clipping studies conducted on the Santa Rita range south of Tucson, Ariz. (30), showed an average annual forage production of about 1,160 lb. per acre. Hay harvesting operations gave yields of 640 lb. per acre. Good grasslands will support a cow on 35 acres per year. On grass-browse mesa lands a cow requires 45 to 50 acres and on the driest deserts, about 70 acres.

THE BUNCH-GRASS REGION

A large part of the bunch-grass region of the Northwest has been cultivated, and the remainder has been so thoroughly invaded by sagebrush and annual species as to make very difficult the determination of its original nature. At one time, it must have rivaled any forage region west of the Rocky Mountains in productivity.

Distribution of the Bunch Grass. These grasslands lie between the heavily timbered Cascade Range and the Rocky Mountains in the northern intermountain region and extend from the Okanogan highlands in Washington south to about southern Idaho and Oregon, interrupted only by the Blue Mountains. Extensive areas also occur in western Montana east of the Bitterroot Range. Originally, this prairie likely occupied many of the central and coastal valleys of California.

Great uncertainty exists as to exact extent of the bunch grasses originally since, with overgrazing, sagebrush has invaded the intermountain grasslands from the south, and annual grasses have completely occupied the California valleys. Many ecologists hold that much of southern Idaho, eastern Washington, eastern Oregon, western Montana, and large areas of northern Nevada and Utah are climax grassland (25). Research and early records tend to bear out this viewpoint in many respects. Climatically, however, this area differs from the major grasslands, which characteristically receive most of their precipitation during the summer or growing season (20, 22). In this region of spring rainfall, grasses grow in spring and then dry up during the rainless summer.

Physical Conditions. The bunch-grass type occurs over a wide variety of soil and climate. The soils under well-developed bunch grass are black, deep, high in lime and organic matter, and highly productive. Typical of this area are the famed Palouse wheatlands of eastern Washington, which are cultivated almost in entirety.

The precipitation of the bunch-grass region is low, ranging from about 8 to 20 inches. Most of this falls from early September to early April, mostly in the form of snow. Only about 10 per cent of the rainfall in the California area comes during the summer season. Growth occurs mainly during the early-spring months, the vegetation remaining dormant during the dry summer. In the Palouse area, the grasses are mature and dry by the first of July. A long frost period during the winter and a dry summer period force vegetation to remain dormant during the greater part of the year. Only during a brief spring period does frost-free temperature overlap the moist-soil period. During this time alone can the

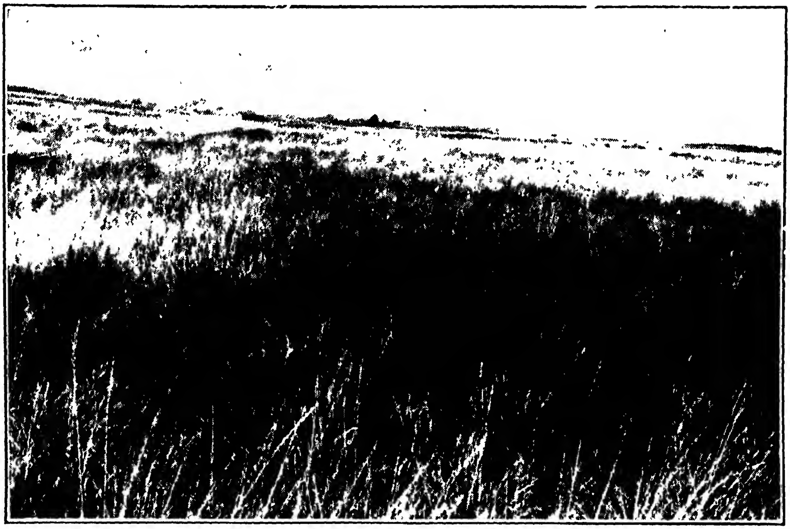

FIG. 19. In areas of abundant precipitation in eastern Washington, the Palouse grasslands are dominated by *Agropyron spicatum* and *Festuca idahoensis*, which form dense stands of high grazing capacity.

comparatively shallow-rooted grasses grow. Fall growth occurs only in unusually favorable years.

Natural Vegetation. Clearly, the most important grasses of the intermountain bunch-grass region are the bunch wheatgrass (*Agropyron spicatum*) and its close relative *A. inerme* (Fig. 19). Idaho fescue (*Festuca idahoensis*), needlegrass (*Stipa comata*), Sandberg bluegrass (*Poa secunda*), Junegrass (*Koeleria cristata*), and big bluegrass (*Poa ampla*) are the associated grasses. Bottomlands and clay soils often are dominated by giant ryegrass (*Elymus cinereus*) and western wheatgrass (*Agropyron smithii*). Sandy soils and rocky soils may support Indian ricegrass (*Oryzopsis hymenoides*), needlegrass (*Stipa comata*), and sand dropseed (*Sporobolus cryptandrus*). Annual bromes, downy bromegrass (*Bromus

tectorum) and others, have invaded the area almost everywhere as a result of fire and heavy grazing. Only in the more moist borderlands are broad-leaved herbs important. Balsamroot (*Balsamorhiza* spp.), lupine (*Lupinus* spp.), yarrow (*Achillea* spp.), mule-ear dock (*Wyethia* spp.), and little sunflower (*Helianthella* spp.) are locally abundant.

In the California valleys many ecologists believe the bunch grass *Stipa cernua* to be the original dominant with associated species being *Poa scabrella*, *Stipa pulchra*, *Melica imperfecta*, *Sitanion hystrix*, and *Elymus triticoides* (25). Such great changes have taken place, however, that the

FIG. 20. Annual grasses have succeeded in entirely replacing the former bunch-grass cover over thousands of acres in California. These lands furnish excellent grazing for cattle in the spring, but when the grasses dry in early summer, the forage is poor in nutritive value.

conditions which originally obtained are but imperfectly known. At present less than 5 per cent of the herbaceous cover is made up of perennials (19). Most of the valleys are now under irrigation and cultivation. Remaining range lands, because of fire and heavy grazing, are completely and probably permanently occupied by annuals. The area can be referred to as the California annual grassland and should be managed as such. This annual cover (Fig. 20) is dominated by *Avena fatua;* but this is closely rivaled by several species of brome, chiefly *Bromus hordeaceous*, *B. mollis*, *B. rubens*, *B. rigidus*, and *B. tectorum*. Other important annual grasses are *Hordeum murinum*, *H. pusillum*, *Festuca myuros*, and *F. megalura* (25). Forbs are of secondary importance in this type, though the number occurring is large. From a grazing viewpoint, bur clover (*Medi-*

cago hispida) and alfilaria (*Erodium cicutarium* and *E. botrys*) are important constituents and furnish abundant forage. On foothill ranges a more or less open savanna largely of oak, pine, and *Ceanothus* is common over this annual-grass type.

Perhaps the major disadvantage of the annuals is that they are short-lived. Their shallow root systems enable them to keep green only while the surface soil is moist. They start growth upon arrival of the winter rains; but drought follows shortly thereafter, and usually by April the grasses begin to mature and are soon dead. The dried material cures poorly and leaches rapidly. Protein deficiencies become serious in early summer, and normal gains can be expected thereafter only with careful supplementing. Consequently, cattle are grazed largely in fall and winter, although in many operations they remain yearlong on foothill ranges (3). Green forage is available most years from February to May.

THE INTERMOUNTAIN SHRUB REGION

The intermountain region, which lies between the Rocky Mountains and the Sierra Nevada and Cascade Range, is dominated over the majority of its area by deeply rooted, semidesert shrubs, almost all of which belong either to the Compositae or to the Chenopodiaceae families. Most of Nevada and Utah are in this region, and it extends into western Colorado, northern Arizona, eastern California, and much of the western half of Wyoming. Its original northern limit is much disputed, but present range includes about one-fourth of Oregon, in the southeast, and most of the southern half of Idaho.

Physical Conditions. The intermountain shrub region is irregular topographically and hence is highly variable in soil and climate. Poor drainage conditions coupled with low precipitation result in concentrations of soil salts in the lowlands, and these greatly influence the vegetation. Soils generally are shallow and rocky, many having no profile development.

Precipitation tends to be more abundant in the nongrowing season, and the summers are hot and dry. As a result, vegetation is deep-rooted or matures before summer droughts begin. Temperatures are low during the winter months; hence, growth is confined to a brief spring period. Plant growth, even with the best management, is necessarily limited.

Natural Vegetation. The intermountain shrub region is dominated by the big sagebrush (*Artemisia tridentata*) (Fig. 21) and black sage (*Artemisia nova*). Second to the sagebrushes in importance and occurring on drier and saltier soils is shadscale (*Atriplex confertifolia*) (Fig. 22). Additional important shrubs are rabbitbrush (*Chrysothamnus nauseosus*), yellowbrush (*C. viscidiflorus* and *C. stenophyllus*), greasewood (*Sarcobatus*

vermiculatus) (Fig. 23), snakeweed (*Gutierrezia sarothrae*), mat saltbush (*Atriplex nuttallii*), winterfat (*Eurotia lanata*), Mormon tea (*Ephedra* spp.), and in southern extremes, blackbrush (*Coleogyne ramosissima*). Sharp zonation of these species, likely a result of salt accumulations, is common. Almost pure stands of a single species are not at all unusual. Associated with the deeply rooted shrubs of the intermountain region are a number of grasses and forbs. The most important grasses are bunch wheatgrass (*Agropyron spicatum*) and squirreltail (*Sitanion hystrix*). A large part of this type may have once been dominated by the wheat-grasses, with sagebrush occurring only as a subdominant.

FIG. 21. Sagebrush, *Artemisia tridentata*, dominates millions of acres of dry range land in the intermountain region. It is a dull gray to blue-green in color and has but little grazing value.

The invader *Bromus tectorum* is an early-maturing associate in the sage-brush type. This plant is ideally suited to grow in a dry habitat, for it matures and produces seed during the brief spring period when the soil is still moist from the winter's snows. Other grasses locally important are *Oryzopsis hymenoides*, *Hilaria jamesii*, *Stipa comata*, *Agropyron smithii*, *Elymus cinereus*, and various species of *Poa*, mostly *P. secunda*.

Forbs are strikingly unimportant in the climax sagebrush type. Though local exceptions are common, on drier desert portions there is no important forb associate except desert mallow (*Sphaeralcea coccinea*). On more moist foothill zones *Balsamorhiza*, *Lupinus*, *Wyethia*, *Aster*, and *Astragalus* are common. Throughout the region, annuals, mostly downy brome-

grass and mustards, are common invading species. Russian thistle is abundant under recurrent disturbance. The newly introduced *Halogeton glomeratus* is rapidly invading much of the region, especially Nevada, Utah, and southern Idaho.

Grazing Value of the Intermountain Shrub. The big sagebrush type and the shadscale type in their grazing use are somewhat distinct, the sagebrush being essentially a spring and fall range and the shadscale a winter range. Since it occupies the moister areas, sagebrush is the more productive of the two. A thrifty growth of this plant indicates deep soil and good moisture conditions. A large part of the type, therefore, has been culti-

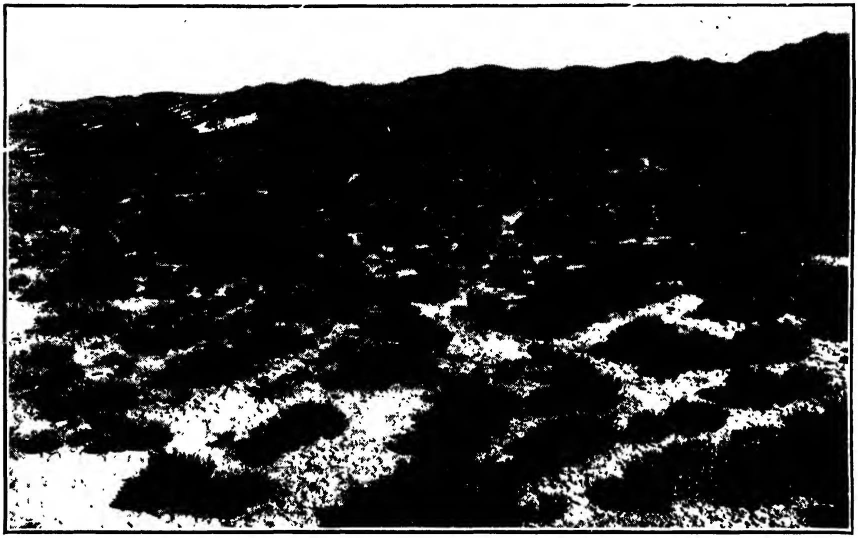

FIG. 22. Shadscale, *Atriplex confertifolia*, is abundant on dry and salty soils throughout the intermountain shrub region, occurring often in almost pure stands.

vated and removed from grazing. Naturally, the most productive sites have been thus affected, although the remaining area still serves as the most important spring and fall range in the intermountain region. Spring range is such a vitally important link between the vast winter and summer ranges of the West that the value of these sagebrush lands is far higher than their grazing capacity ordinarily would merit. Since the big sagebrush lands are spring and fall range and since this season is marked by deficient grazing area, heavy overgrazing on the type has been almost universal.

Shadscale and black sage types reach greatest importance on lower elevations of Nevada and Utah where, despite the low productiveness of the soil and climate, these vigorous shrubs furnish winter grazing for thousands of sheep and many cattle as well. It is estimated that the salt-

desert-shrub type occupies about 41 million acres (23), almost all of which has remained as range land because of inherent dryness or heavy alkali prohibiting cultivation. Continued grazing after spring growth starts has been responsible for much damage, though this condition is being eliminated since federal control of the former public-domain lands has been initiated. These desert shrubs are high in protein, phosphorus, and vitamins and are the backbone of the intermountain winter sheep ranges.

THE SOUTHERN DESERT-SHRUB REGION

The southern desert-shrub region is a vast and arid land centering in southern California, southern Nevada, and southwestern Arizona, though long arms extend across southern New Mexico and far down the border of western Texas. This region has the most arid climate in North America (Fig. 24). The plants of this region resist drought in many ways. Wide spacing is characteristic, for most of the shrubs require widely spreading root systems to secure vital moisture. Fleshy plants are common; and these draw enough water from temporary surface moisture following rains to saturate their hydrophilic storage cells. This water is used to tide the plants over until the next rain. Many plants leaf out in the wet seasons and drop their leaves upon the inception of drought. Many annual plants survive by their ability to grow rapidly and set seed during the wet season. Only the dormant seeds pass through the hot, dry period.

FIG. 23. Greasewood (*Sarcobatus vermiculatus*) is common on alkaline lowlands throughout most of the West. See also facing page.

Physical Conditions. Climatically, the southern desert shrub is comparable with no other region in the West. Precipitation is far below optimum for most plant growth, the average being only 3 to 5 inches annually, with individual years producing less than 1 inch in some places. This situation is complicated further by exceedingly high evaporation rates reaching 120 to 150 inches per year.

Frequent and prolonged drought periods are common. In Nevada, California, and western Arizona precipitation falls largely during the winter. Over the rest of the area there are two rainy seasons: summer and winter. Throughout the region the winter rains fall primarily during December, January, and February. When summer rains occur, these usually fall during July, August, and September.

Temperatures in the desert region are rather high, maximums of 110 to

FIG. 23. (*Continued*)

115°F. occurring rather frequently over much of the area. The frost-free period is long, and temperatures below 25°F. occur infrequently.

Natural Vegetation. The vegetation of the southern desert shrub is predominantly woody, though the region is characterized more than any other in North America by its large number of species and the variability of their growth habits. The most widespread dominant is the almost worthless creosotebush (*Larrea divaricata*). Since man occupied the deserts, this species has increased not only in density but also in area. It frequently forms stands in which no other perennial grows (Fig. 45). Over

FIG. 24. The southern desert-shrub region is dominated by large and frequently deeply rooted woody and fleshy species. These are spaced far apart and form an exceptionally low density.

rather extensive areas that were once grassland it forms a savanna which prevents development of a normal stand of grass. In spite of this, the stand is not dense; exclusion of other species is achieved by a widely spreading root system, which occupies the area more thoroughly than the crowns indicate.

A second shrub that is common over large areas is the low-value bur sage (*Franseria deltoidea*). This is a low-growing grayish shrub occurring, often, as an understory to the taller species. The very dry and hot western sections support great numbers of the more palatable white bur sage (*Franseria dumosa*). Lending a characteristic appearance to the desert through much of its area are the many species and forms of prickly pear, cholla, or other cacti. These include species of *Opuntia*, *Cereus Ferocactus*, and *Echinocactus*. Bottomlands and moister flats (Fig. 25) are

characterized, often, by dense stands of mesquite (*Prosopis juliflora*) and screwbean (*P. odorata*). Where alkali is moderately high, desert saltbush (*Atriplex polycarpa*) dominates wide areas (17, 30). Common upland shrub species are catclaw (*Acacia greggii*), whitethorn (*A. constricta*), huajillo (*Calliandra eriophylla*), tarbush (*Flourensia cernua*), paloverde (*Cercidium microphyllum*), ironwood (*Olneya tesota*), canotia (*Canotia holocantha*), and ocotillo (*Fouquieria splendens*).

Associated Species. In addition to these shrubs many herbaceous plants occur as an understory. Some of the most abundant are annuals

FIG. 25. Mesquite, *Prosopis juliflora*, varies in size from a bush to a small tree and usually occurs as a savanna with desert grasses. It occupies tremendous areas of the Southwest and is increasing in abundance rapidly. See also Fig. 18.

that are ideally suited to the desert climate and some of which furnish a wealth of forage. Chief among these are alfilaria or filaree (*Erodium cicutarium*) and Indian wheat (*Plantago purshii*).

Most important to the livestock industry is alfilaria, which grows best in March and April, furnishing, in good years, a dense growth of well-liked and nutritious forage. Unfortunately this plant, like all annuals, is undependable; and though forage is abundant in wet years, it may be almost entirely absent in dry years.

Although the original condition of the southern desert is difficult to reconstruct, there seems to be little question that perennial grasses were once more abundant, at least in the less arid portions, than they are today. In the eastern portions of the area, grasses become increasingly abundant with increasing precipitation until the desert-shrub region

fades imperceptibly into the desert-grass region. For this reason many of the dominants of the desert-grass region occur in the higher or eastern parts of the desert-shrub type.

Important perennial grasses that occur in the desert-shrub region are bush muhly (*Muhlenbergia porteri*), tobosagrass (*Hilaria mutica*), and big galleta (*H. rigida*).

Bush muhly (*Muhlenbergia porteri*) was originally a much more important forage species in the southern desert shrub than it is today. It grows on a wide variety of nonalkaline soils, enduring great extremes of drought and of high temperature (30). Being highly preferred yearlong by livestock and having poor seed habits, it has been greatly damaged by overgrazing.

Grazing Value of the Southern Desert Shrub. Because of unfavorable growth conditions, the southern desert shrub probably never has been a productive range land, but at present it is materially lower than originally. Many of the browse species are not usable by stock, with the exception of the fruits. Grasses and forbs may furnish more forage locally than do the browse species. Sheep are grazed in some parts, especially during the winter; but they are far outnumbered over the region as a whole by cattle.

Because of the hot and dry condition of the desert range, much of it is used but a short part of each year. Though the palatable shrubs remain nutritious, the annual plants remain green but a few weeks and become almost worthless when dry. Stock water becomes a critical problem, for surface water is scarce and wells must be unusually deep.

Over much of the desert, it is impossible to obtain enough stock to use the wealth of annual forage that may be available for a few weeks after an exceptionally good rainy season. Livestock, mostly cattle, are sometimes brought in from other ranges or from the feed lot and pasture to harvest the crop of annuals. These animals are removed when the forage becomes dry. Because of the uncertainty of the rains and the lengthy drought periods, some of the range is used on a temporary basis. On much of it, however, the shrubs, many of which are evergreen, permit grazing yearlong.

THE CHAPARRAL REGION

The term "chaparral" is of Mexican origin; it means, specifically, evergreen scrub oak or oak brush (18) but has come to apply to almost any shrub type. It is unfortunate that the term is used so loosely; it would be desirable to confine it to the evergreen shrub type of Arizona and southern California. This type is different from any other shrub type in the United States and should not be confused with the shrub types common in other regions.

The chaparral region is essentially a southern region with a hot and dry climate. Mean annual precipitation in the Rocky Mountain chaparral varies from 15 to 20 inches; in southern California from 10 to 20 inches (25). In northern California and Oregon, however, it may be as much as 60 inches.

In part because of its extensive geographical range, the chaparral is characterized by great botanical differences as well as differences in range use. For purposes of simplification it is here divided into three subregions or types. These are (*a*) the California or true chaparral, (*b*) the oak scrub, and (*c*) the mountain brush.

The California Chaparral

The California chaparral occurs over large areas of southern California, extending south from Monterey, and west from the Sierra Nevada to the Mexican line, covering 5½ million acres (18). Vast areas of central and southern Arizona are dominated by the same type of chaparral, which, though greatly reduced in species, is remarkably typical of the California chaparral in appearance (17). The type occurs in isolated areas in northern California as a result of disturbance, usually burning, which greatly favors the chaparral over forest trees. Here *Adenostoma*, *Arctostaphylos*, *Ceanothus*, and *Quercus* dominate temporarily. Extensive chaparral has also been reported at low elevations, where chaparral has invaded grassland (25).

Physical Conditions. Climate in the California chaparral area is characterized by a very light summer rainfall and comparatively heavy winter rainfall. This, coupled with relatively high winter temperatures, results in most of the new growth on the shrubs taking place in the spring, plants appearing brown and lifeless during the summer (18). Summer temperatures are high.

Natural Vegetation. On drier areas at lower elevations, the chaparral growth is open, but the plants tend to have an even distribution. At higher elevations, the shrubs grow very densely, especially on north slopes, forming an almost impenetrable tangle 10 ft. or more in height (Fig. 26). At still higher elevations, the chaparral gives way to coniferous forests, the chaparral never occurring above 8,000 ft.

The California chaparral, because of its density and complexity, almost defies botanical analysis; the problem is complicated further by its extreme heterogeneity. Plummer (18) has recorded estimates of the chaparral composition within the national forests of southern California that were obtained from averaging several hundred observations (Table 16). Other major species are *Ceanothus oliganthus*, *C. sorediatus*, *C. spinosus*, *Arctostaphylos pungens*, *A. glandulosa*, *A. viscida*, *A. canescens*, *A. tomentosa*, *Prunus ilicifolia*, *Rhamnus crocea*, and *R. californica* (14, 25).

Open stands of brush support a valuable undercover (19) of foxtail fescue (*Festuca megalura*), red brome (*Bromus rubens*), hairgrass (*Aira caryophyllea*), and needlegrasses (*Stipa* spp.).

Grazing Value of the California Chaparral. Undoubtedly, the chief function and highest use of the California chaparral vegetation are as watershed protection. The chaparral region is subject to erosion because of steep slopes, torrential rains, and frequent fires. Further, the valuable and intensively used farm lands on the coastal benchlands depend upon the

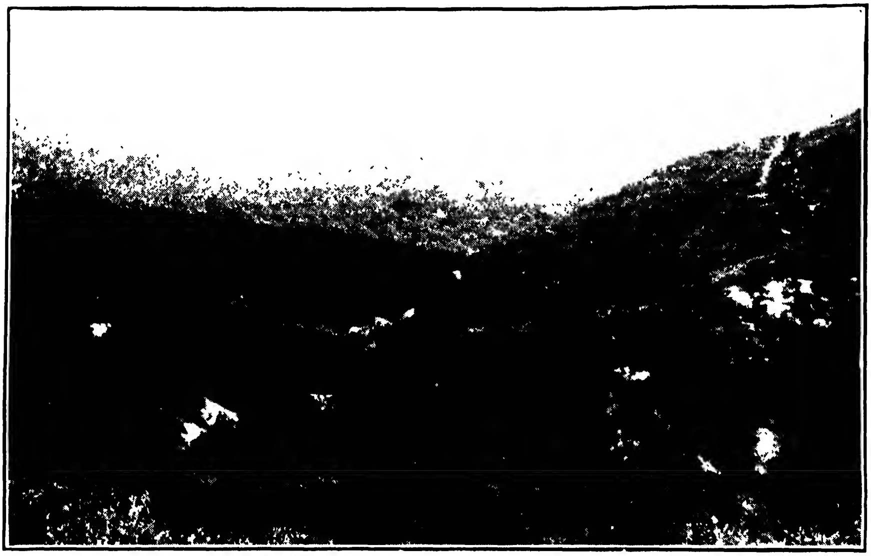

FIG. 26. The California chaparral is very dense and, in areas of high precipitation, it forms an almost impenetrable tangle.

chaparral-covered mountain slopes for irrigation water, and the coastal cities for culinary water.

Livestock obtain some forage from the chaparral. During emergencies such as drought, some parts of the area are grazed by all classes of stock. Goats seem to do well on this ration; in some limited areas, goat grazing is common. Sheep and cattle can enter dense stands only with difficulty; for cattle, especially, chaparral generally is considered almost worthless.

The Oak Type

Scrub oak occupies vast areas in the West, especially in the southern areas, sometimes almost to the exclusion of other shrubs. There are many species of oak, some live or evergreen and some deciduous, and they occupy a variety of habitats. The brush stand may be very dense, virtually excluding low-growing vegetation, or it may be merely an open

savanna over grass or low shrubs. The oak itself is seldom of great importance to grazing animals, with the exception of the acorns, which are extensively used in some instances.

The oak types of the intermountain and Rocky Mountain foothills are composed of small and close-growing species, mainly *Quercus gambelii*, *Q. turbinella*, and *Q. undulata*. These areas usually are covered by a growth of shrubs so dense as to make grazing difficult but usually not impossible (Fig. 27).

TABLE 16. PERCENTAGES OF DOMINANT SPECIES OF THE SOUTHERN CALIFORNIA CHAPARRAL

Data from Plummer (18)

Species	*Percentage of total density*
Adenostoma fasciculatum	33
Adenostoma sparsifolium	6
Arctostaphylos glauca	6
Arctostaphylos manzanita	4
Artemisia californica	4
Ceanothus crassifolius	1
Ceanothus cuneatus	3
Ceanothus divaricatus	8
Ceanothus hirsutus	1
Ceanothus papillosus	1
Cercocarpus parvifolius	5
Eriogonum fasciculatum	2
Photinia arbutifolia	1
Quercus dumosa	13
Quercus wislizeni	1
Salvia mellifera	1
Other species	10

Much of the California grassland supports an open cover of oak trees. *Quercus wislizeni*, *Q. douglasii*, and *Q. dumosa* are important, though many other species occur. Savannas are found also in southern Arizona where oaks, mainly *Quercus emoryi* and *Q. oblongifolia* (20), grow in mixture with desert grassland. Similar stands, mostly post oak (*Quercus stellata*), occur in central Texas.

In southeastern New Mexico, a large oak type occurs, consisting of low-growing shin oak, mostly *Quercus havardii*, associated with grass species and a few desert shrubs. Similar shin oak areas are found through the southern portion of the mixed-grass prairie on sandy soils (25). Many plant geographers rank these types as grass rather than oak (Fig. 28).

In grazing use, the dense scrub oak types of the Rocky Mountain and intermountain regions are analogous to the mountain brush and piñon–juniper types, being used to best advantage as spring and fall range. Not infrequently, however, they are grazed yearlong. The oak-grass savannas

Fig. 27. Dense stands of *Quercus gambelii* dominate wide areas of the foothill ranges of the Rocky Mountains.

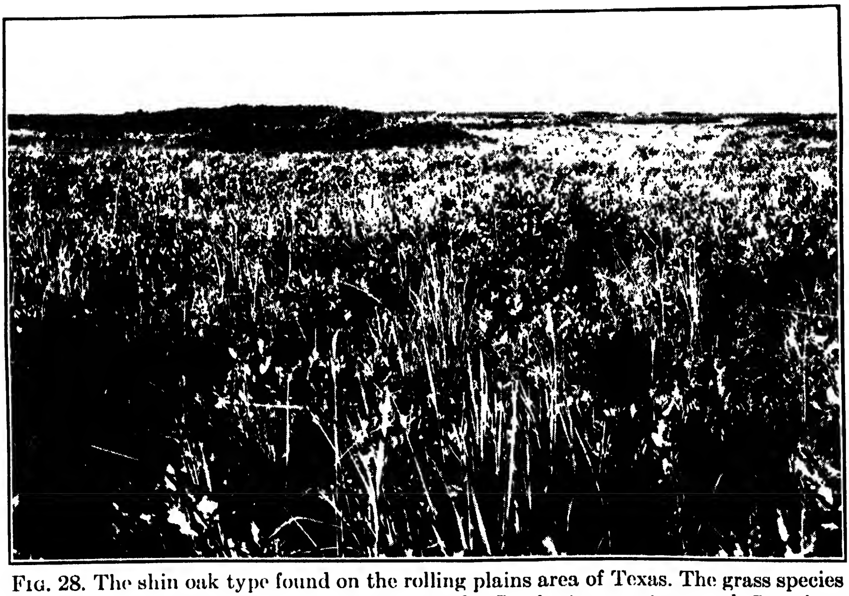

Fig. 28. The shin oak type found on the rolling plains area of Texas. The grass species are *Andropogon scoparius*, *Andropogon gerardi*, *Sorghastrum nutans*, and *Bouteloua curtipendula*. The oaks in this type, mostly *Quercus havardii*, are seldom over 24 inches in height, and in cases of severe depletion the oaks may dominate to the exclusion of grasses. (*Courtesy of the U.S. Soil Conservation Service.*)

of California and the Southwest, generally, are used yearlong, as are the adjacent grasslands.

The Mountain-brush Type

The mountain-brush type usually exists as narrow strips or transition zones between coniferous forest and grassland or sagebrush land. Like the California chaparral, it does not extend far northward but reaches its best development in Utah, Arizona, New Mexico, and Colorado. It also occurs

FIG. 29. Northern coniferous-forest lands after burning may remain for long periods in brush such as *Symphoricarpos, Acer, Salix, Amelanchier, Prunus, Holodiscus,* and *Ceanothus.*

commonly in scattered areas largely as a transition between the California chaparral and the coniferous forest. In California, it exists as the *soft chaparral* of Jepson (14) in contrast to the true chaparral. Undoubtedly both climax and developmental stages are represented in what may be classified as the mountain-brush type (Fig. 29).

Perhaps nothing characterizes the vegetation of the mountain-brush type so much as its variability. No single species can be said to dominate the type, for the great variety of soil and climate causes first one and then another of the many constituents to exert local dominance. Outstanding genera are *Cercocarpus, Amelanchier, Symphoricarpos,* and *Ceanothus.* These four genera are represented by several important species, and many other genera are locally important. Among these are *Acer, Artemisia,*

Holodiscus, Prunus, Physocarpus, and *Rubus.* From the point of view of grazing value the following are considered of especial value:

Cercocarpus montanus	*Cowania stansburiana*
Amelanchier alnifolia	*Sambucus caerulea*
Prunus virginiana	*Rosa* spp.
Purshia tridentata	*Symphoricarpos* spp.

Generally, the mountain-brush type is open, with considerable grass and forb growth as an understory. This, together with the high preference and nutritive value generally characteristic of the shrubs, makes the type valuable for grazing despite the drought and rough topography that typify it. This area is grazed to best advantage during the spring and fall, and it forms an important link in the seasonal movement of stock in many parts of the West. Only its small area prevents this type from holding a foremost position of importance as a source of range forage.

THE PINON-JUNIPER REGION

The piñon–juniper region is characterized by low-growing conifers that are not lumber-producing species. Grazing thus becomes the chief use of this land. The common species of piñon pine are *Pinus edulis* and *P. monophylla;* the junipers are chiefly *Juniperus monosperma, J. utahensis, J. pachyphloea,* and *J. scopulorum.* These small trees, either alone or in mixture, form an open overstory on vast areas of the western foothill lands and give to these hills a characteristic woodland aspect (Fig. 30).

The piñon–juniper region is characteristic of the southern ranges, only scattered stands occurring north of the 42d latitude.

Physical Conditions. The piñon-juniper lands, generally, are intermediate in elevation, lying between the desert shrubs or grasses and the coniferous forests, at elevations seldom above 6,000 ft. This intermediate foothill area, generally, is steep, and erosion removes the soil rapidly. It is characterized by less than 16 inches precipitation per year and high temperatures. The shallow rocky soil is generally low in productivity.

Often in the northwest portion of its range, the piñon–juniper region seems to be close to sagebrush in its ecological requirements, the two being sometimes mixed and sometimes separated into small alternes, the sagebrush usually occurring on the moister, deeper soils; the piñon–juniper on the drier and more rocky sites.

Juniper throughout the West appears to be invading adjacent types of vegetation, possibly as a result of decreased fires and increased grazing (Fig. 30). Junipers in the Southwest are fast becoming a serious range pest, and expensive control measures have been instigated in many areas.

Natural Vegetation. Unfavorable growing conditions make the piñon–juniper region one of the lowest-producing of all western range areas. Except where juniper has invaded grasslands, it is doubtful whether much of this region ever produced an abundance of forage, though it was a source of valuable early-spring feed. Forage was chiefly of the following species: bitterbrush (*Purshia tridentata*), sagebrush (*Artemisia tridentata*), mountain mahogany (*Cercocarpus* spp.), cliff rose (*Cowania stansburiana*), blue bunch wheatgrass (*Agropyron spicatum*), western wheatgrass (*A. smithii*), blue grama (*Bouteloua gracilis*) needle grass (*Stipa* spp.);

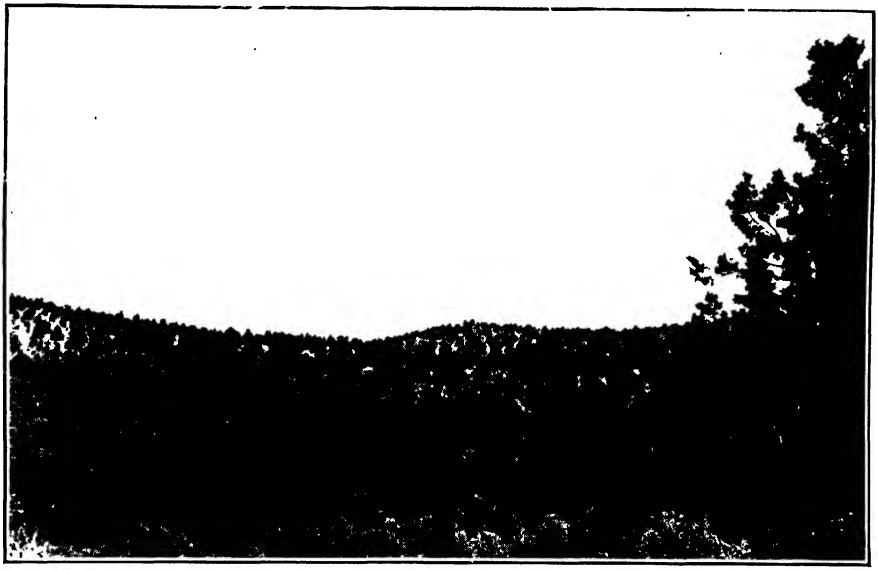

FIG. 30. A typical stand of juniper, *Juniperus utahensis*. Open stands and rough, rocky topography are common. Note young trees invading adjacent sagebrush range.

galletagrass (*Hilaria jamesii*), Indian ricegrass (*Oryzopsis hymenoides*), sideoats grama (*Bouteloua curtipendula*), and muhly (*Muhlenbergia* spp.). Russian thistle (*Salsola kali tenuifolia*) and downy bromegrass (*Bromus tectorum*) also have become an important part of the forage in the northern and central portions of the piñon–juniper region.

Grazing Value of Piñon–Juniper. Since piñon and juniper are characteristic of hot, dry slopes at intermediate elevations, the region is ideally suited for spring range, especially lambing range. Much of the land lying between the desert winter ranges and the high mountain ranges is cultivated. Since the piñon–juniper soil is shallow and rocky, it has escaped cultivation and now is often made to support the livestock that once grazed a much vaster acreage during the spring grazing season. Extensive damage, estimated to have caused 60 per cent depletion, has

resulted (23). Almost no forage remains in many areas and animals have been forced to eat large quantities of the trees themselves. The consumption of some of this coniferous foliage appears to be normal during cold periods on winter ranges, but domestic stock could be expected to consume little or none of it on correctly used spring ranges. Deer use somewhat more than livestock.

THE CONIFEROUS-FOREST REGION

The coniferous-forest region, occupying higher and hence moister mountainous lands throughout the West and forming an almost complete cover on the northwestern coastal area, is characterized by evergreen trees mostly of the genera *Pseudotsuga*, *Pinus*, *Picea*, and *Abies*. Since precipitation varies from 15 to 100 inches per year, altitude from sea level to some 12,000 ft., and temperature from almost frost-free to the extremely cold and short growing season of the high Rocky Mountains, there is a great vegetal variation within the region. Open stands of small trees of the Southwest and Rocky Mountain foothills support a dense undergrowth of forage plants (Fig. 31). Many of the dense and tall-growing forests of the Northwest, on the other hand, support little undergrowth and are of almost no value to livestock. Of the vast open coniferous forest in the West, some 68 million acres cannot be grazed because of steep topography, insufficient forage, and dense tree growth (23). Many forest types have large open parks supporting excellent stands of desirable grass; and the alpine grasslands occurring on high mountains above timber line, though usually small, are highly productive of forage. The high precipitation of these grasslands normally results in a dense forage growth wherever a too-dense timber stand does not interfere, and most of it is intensively used during the short summer season by both cattle and sheep.

The range in the coniferous-forest region generally is in much better condition than in other regions because of the great proportion of these lands that has been under federal control. This region is the main summer grazing land of the West and, as such, is of greater importance than its acreage would suggest. It is also highly important as watershed through most of its range.

Unfortunately, the topography of this region makes uniform stock distribution difficult; hence, many accessible valley bottoms, hilltops or mesas, and open level parks are heavily overgrazed. Forest Service (23) calculations on the open forest types show a decrease in grazing capacity from a virgin condition of 4.0 acres per animal-unit month to 5.9 acres by 1936, a 33 per cent depletion.

Four distinct areas may be recognized in the coniferous-forest region: (*a*) the southern Rocky Mountain, essentially Arizona and New Mexico;

(*b*) the central Rocky Mountain, including the Colorado Rocky Mountains and the Wasatch Range in Utah; (*c*) the northern Rocky Mountain, centering in northern Idaho and western Montana; and (*d*) the Northwest, including western Washington and Oregon and northern California. Although these sections are not always distinct, they are characteristically different and each has its peculiar problems.

Fig. 31. Under protection from grazing for over 20 years this stand of *Pinus ponderosa* has produced an undercover of valuable forage plants dominated by *Purshia tridentata* and *Stipa comata*.

The Southern Rocky Mountain Coniferous Forest

The southern coniferous forests are found in the mountainous regions of Arizona and New Mexico at elevations of 6,000 to 12,000 ft. This area, being the most southern of the forested lands, has a longer growing season, warmer temperatures, and lower precipitation than most. The topography is rough, though relatively flat-topped mesas are common. The soils are shallow and rocky throughout most of this section.

Natural Vegetation. The forest type of greatest abundance and extent and of far the most importance as grazing land in both Arizona and New

Mexico is dominated by ponderosa pine (*Pinus ponderosa*). Though this tree reaches its best development at elevations of 6,000 to 8,500 ft., the ponderosa pine occurs in mixture with Douglas fir (*Pseudotsuga taxifolia*) to elevations as high as 10,300 ft. and as low as 5,300 ft. (29). In addition to the pine type is a type dominated by Douglas fir at elevations of 8,000 to 10,000 ft. and one dominated by spruce, primarily *Picea engelmannii*, at elevations above about 9,000 ft. Neither of these rivals the ponderosa type in size or importance for grazing and timber production.

The major grasses on the more open mountain ranges are Arizona fescue (*Festuca arizonica*), pine dropseed (*Blepharoneuron tricholepis*), mountain muhly (*Muhlenbergia montana*), little dropseed (*Sporobolus confusus*), and bluegrasses (*Poa* spp.). Shrubs, which sometimes occupy an important position under the most open stands of ponderosa pine, especially on rocky hillsides, are cliff rose (*Cowania stansburiana*), snowberry (*Symphoricarpos* spp.), serviceberry (*Amelanchier* spp.) and mountain mahogany (*Cercocarpus montanus*).

Forbs important as forage throughout this southern forest include species of *Lupinus*, *Aster*, *Senecio*, *Delphinium*, *Agoseris*, *Achillea*, and *Erigeron*.

Grazing Value of Southern Rocky Mountain Forest. Most of the ponderosa pine type is open and supports an abundant stand of forage plants. In addition, the many dry parks and meadows of the higher forests provide excellent forage. Much of the Douglas fir–spruce area is forested so densely, however, as to make it of little value for grazing. Many stands prevent even the most shade-tolerant shrubs from gaining a foothold, and only a litter of needles and cones is found under the trees (17).

Both cattle and sheep are grazed on the southern coniferous forest where usually they remain for 4 to 6 months during the summer. Some forests are grazed during the mild winter months, and lower grasslands are grazed during the summer, when the forage species make their best growth. The grazing capacity of the forest is dependent upon the elevation and openness of the tree cover. It varies from practically valueless stands of dense trees to open park and meadow grasslands, some of which can furnish one animal-unit month of grazing per acre. An average of 5 to 10 acres per animal-month is typical.

The Central Rocky Mountain Coniferous Forest

The central portion of the Rocky Mountains supports a cover of coniferous trees, generally small, with a more or less dense stand of browse, grass, and forbs as an understory. Though much lumber is cut from this area, the trees are small, and lumbering in many places is not a major consideration in managing the land.

The grazing of livestock is of great importance over a major portion of the area. The topography is very rough, and large tracts are not available to animals because of steep or rocky slopes. The climate is characterized by short summers, with a 2- to 3-month growing season. Precipitation is generally between 15 and 40 inches, most of it snow, hence grazing is largely in summer only.

Four distinct divisions can be delimited in this area according to the dominating vegetation, as follows: (*a*) ponderosa pine, (*b*) Douglas fir–aspen, (*c*) spruce-fir, and (*d*) alpine tundra.

The Ponderosa Pine Zone. The ponderosa pine is of more limited extent in the central mountains than in the southern mountains. In Colorado it dominates vast areas of the low foothills, frequently coming in direct contact with the grass plains of eastern Colorado or with piñon–juniper. Although ponderosa pine commonly occurs in pure stands, Douglas fir is abundant at high elevations and throughout on north slopes. Treeless mountain parks are common, grasses or big sagebrush being the usual dominants.

In the parks and open timber stands, the dominant grasses are Arizona fescue (*Festuca arizonica*) and mountain muhly (*Muhlenbergia montana*). Idaho fescue (*Festuca idahoensis*) and spike fescue (*Hesperochloa kingii*) take the place of *Festuca arizonica* in the northern part of Colorado and Wyoming. Other important grasses are: little bluestem (*Andropogon scoparius*), pine dropseed (*Blepharoneuron tricholepis*), slender wheatgrass (*Agropyron trachycaulum*), Junegrass (*Koeleria cristata*), and oatgrasses (*Danthonia intermedia, D. parryi*). Blue grama (*Bouteloua gracilis*) is common and of greatest importance only in the lower edge of the ponderosa pine zone where it comes in contact with piñon–juniper and oak.

Heavy grazing over large areas has caused the replacement of bunch grasses by bluegrass (*Poa pratensis*), needlegrass (*Stipa robusta*), muhly (*Muhlenbergia filiformis*), squirreltail (*Sitanion hystrix*), golden aster (*Chrysopsis villosa*), rubberweed *Actinea richardsonii*), and fringed sage (*Artemisia frigida*). Other less desirable species, such as downy bromegrass (*Bromus tectorum*) and snakeweed (*Gutierrezia sarothrae*), are locally abundant.

Common shrubs are big sagebrush (*Artemisia tridentata*), chokecherry (*Prunus virginiana*), serviceberry (*Amelanchier* spp.), snowberry (*Symphoricarpos* spp.), bitterbrush (*Purshia tridentata*), and mountain mahogany (*Cercocarpus montanus*).

Meadow and stream-bank communities furnish an important part of the forage. Important species are hairgrass (*Deschampsia caespitosa*), pinegrass (*Calamogrostis canadensis*), various species of *Carex*, and a variety of woody plants such as shrubby cinquefoil (*Potentilla fruticosa,*

birches (*Betula fontinalis, B. glandulosa*), and dogwood (*Cornus stolonifera*).

The Douglas Fir–Aspen Zone. The Douglas fir–aspen zone is a highly important forest grazing zone throughout the central Rocky Mountains. The vegetation is varied, changing with soil moisture and aspect. The principal vegetation types are Douglas fir (*Pseudotsuga taxifolia*), lodgepole pine (*Pinus contorta*), and aspen (*Populus tremuloides*).

The forage value of the Douglas fir area varies considerably. At lower altitudes the vegetation and grazing values are similar to those of the ponderosa pine. At higher elevations and more favorable sites, dense

FIG. 32. Aspen, *Populus tremuloides*, dominates thousands of acres in the western mountain ranges and is underlain by valuable forage plants which form some of the highest-producing ranges in the West.

stands permit of little undergrowth. Similarly, the lodgepole pine grows so densely as to permit little undergrowth. Accordingly, only secondary forage species are to be found, mostly plants such as pinegrass (*Calamagrostis rubescens*), arnica (*Arnica cordifolia*), and huckleberry (*Vaccinium* spp.).

Most of the grazing in this zone is to be found in the treeless parks and in the areas dominated by aspen. Aspen presumably is a subclimax dominant. Its sparse foliage allows considerable sunshine penetration and hence a valuable undergrowth of forage plants (Fig. 32). The zone receives 20 to 25 inches of precipitation, and the soil generally is highly productive.

Among the many important forage species that occur in the aspen type are mountain brome (*Bromus* spp.), fescue (*Festuca idahoensis* and *F. thurberi*), sedge (*Carex* spp.), bluegrass (*Poa* spp.), wheatgrass (*Agropyron* spp.), vetch (*Vicia* spp.), geranium (*Geranium* spp.), bluebell (*Mertensia* spp.), wild pea (*Lathyrus* spp.), yarrow (*Achillea lanulosa*), butterweed (*Senecio serra*), mule-ear dock (*Wyethia amplexicaulis*), serviceberry (*Amelanchier* spp.), and snowberry (*Symphoricarpos* spp.).

On moist sites the understory in aspen stands is predominantly forbs including the following genera: *Heracleum*, *Ligusticum*, *Osmorhiza*, *Angelica*, *Delphinium*, *Rudbeckia*, and *Thermopsis*.

FIG. 33. Open parks and meadows between clumps of spruce and fir at high elevations in the Rocky Mountains furnish excellent grazing, mostly grasses.

The Spruce-Fir Zone. In the spruce-fir zone, dominated by *Picea engelmannii*, *P. pungens*, and *Abies lasiocarpa*, the trees usually grow in clumps, interspersed with open parks or broad meadows (Fig. 33). The climate is severe, and snow may cover the ground until the middle of June. The grazing season is short, but high precipitation results in excellent forage during that season. Both sheep and cattle thrive on these high ranges, and much of the area will support an animal unit for the summer on each 3 or 4 acres. The forage plants are similar to those of the Douglas fir–aspen zone, with but few additional species.

Many grassland parks originally were dominated by Thurber fescue (*Festuca thurberi*), but now many of these areas are characterized by

needlegrass (*Stipa lettermanii*), bluegrass (*Poa reflexa*), Timothy (*Phleum alpinum*), trisetum (*Trisetum spicatum*), cinquefoil (*Potentilla filipes*), sneezeweed (*Helenium hoopesii*), collomia (*Collomia linearis*), and tarweed (*Madia glomerata*).

Sagebrush extensions up to elevations of 10,000 ft. are common. *Artemisia tridentata* is dominant. Other shrubs common at middle and lower elevations in the spruce-fir zone are snowberry (*Symphoricarpos oreophilus*), bitterbrush (*Purshia tridentata*), and rabbitbrush (*Chrysothamnus lanceolatus*).

Wet meadows that occur in this zone support dense stands of redtop (*Agrostis* spp.), brome (*Bromus* spp.), bluegrass (*Poa* spp.). timothy (*Phleum* spp.), hairgrass (*Deschampsia* spp.), sedge (*Carex* spp.), rush (*Juncus* spp.), *Trisetum*, butterweed (*Senecio* spp.), yarrow (*Achillea lanulosa*), and dandelion (*Taraxacum officinale*) and furnish forage to many animals.

The Alpine-tundra Zone. The alpine-tundra zone, which occurs at elevations above timber line, generally 11,000 to 13,000 ft., strictly is not a forest zone, but its characteristics are much more like those of the forest region than those of the arid grassland. Occasional steep slopes and rough, rocky, ledges make grazing difficult, but most of the zone is readily accessible to stock. The grazing season is short, with much of the area covered by snow for 9 to 10 months of the year. This zone is best adapted to summer sheep grazing.

Over large areas the dominant climax species is sedge (*Kobresia bellardii*). Usually present are bluegrass (*Poa alpina*), trisetum (*Trisetum spicatum*), and hairgrass (*Deschampsia caespitosa*). Bluegrasses (*Poa lettermanii*, *P. pattersonii*, *P. rupicola*), sedges (*Carex drummondii*, *C. chimaphila*), mustard (*Draba oligosperma*) sibbaldia (*Sibbaldia procumbens*), and willows (*Salix petrophila*, *S. rivalis*, *S. saximontana*) are common species in favorable sites.

Three alpine communities are common: meadow communities on more sheltered benches, slopes, and level areas where soils are well developed; willow communities of the taller species, especially near the lower borders of the alpine-tundra zone; and alpine marshes where snowbanks contribute to a continuously moist habitat.

In the more favorable habitats in the alpine-summit zone, the following are common: bluegrasses (*Poa alpina*, *P. lettermanii*, *P. rupicola*), sedges (*Kobresia bellardii*, *Carex drummondii*, *C. chimaphila*), woodrush (*Luzula spicata*), mustard (*Draba oligosperma*), sibbaldia (*Sibbaldia procumbens*), and willows (*Salix petrophila*, *S. rivalis*, *S. saximontana*).

Alpine meadows contain a mixture of redtop (*Agrostis humilus*), wild oat (*Avena mortoniana*), hairgrass (*Deschampsia caespitosa*), timothy (*Phleum alpinum*), and many other grasses in association with such forbs

as yarrow (*Achillea lanulosa*), rubberweed (*Actinea grandiflora*), mountain dandelion (*Agoseris aurantica*), arnica (*Arnica mollis*), and avens (*Geum rossii*).

Impenetrable stands of the taller shrubby willows, near the lower edge of the alpine zone, consist of one or more of the following: *Salix glauca lapponum*, *S. brachycarpa*, and *S. planifolia nelsoni*.

Alpine marshes are characterized by sedges (*Carex albo-nigra C. bella*, *C. physocarpa*), and other species such as *Eleocharis palustris*, *Eriophorum angustifolium*, and *Pedicularis groenlandica*.

Grazing Value of the Central Rocky Mountain Forests. The central coniferous-forest area is used by both cattle and sheep in large numbers and forms a very important part of the western range. The animals usually are wintered in the plains or intermountain shrub type, moved to the oak, piñon–juniper. and chaparral regions during the spring, and then moved from the lower to the higher coniferous zones as summer progresses. Many animals spend the spring and fall in the lower coniferous zones. On the eastern slope of the Rocky Mountains where snow is less than on the western slopes, some animals are overwintered on the sunny and wind-swept slopes of the ponderosa pine zone.

The Northern Rocky Mountain Coniferous Forest

The northern Rocky Mountain region of Wyoming, Montana, and Idaho supports a dense stand of timber trees. The northern area differs essentially from the central and southern areas in that the trees reach commercial size and, through most of this area, timber production, and not grazing, is the most important land use. The northern area is similar to the central and southern at lower elevations, but in higher and moister parts a distinctly different composition obtains. The growing season is shortened to 2 to 4 months, with heavy snows and bitter cold characterizing the winter months.

The northern coniferous zone is characterized by the following forage species, progressing from the lower to the higher elevations (16):

A. Ponderosa pine zone:
- Idaho fescue (*Festuca idahoensis*)
- Blue bunch wheatgrass (*Agropyron spicatum*)
- Canby bluegrass (*Poa canbyi*)
- Pinegrass (*Calamagrostis rubescens*)
- Western wheatgrass (*Agropyron smithii*)
- Elkgrass (*Carex geyerii*)
- Niggerwool (*Carex filifolia*)
- Arnica (*Arnica cordifolia*)
- Lupine (*Lupinus* spp.)
- Ninebark (*Physocarpus malvaceus*)
- Snowberry (*Symphoricarpos racemosus*)

B. Lodgepole pine—Douglas fir zone:
  - Bluegrasses (*Poa* spp.)
  - Pinegrass (*Calamagrostis rubescens*)
  - Elkgrass (*Carex geyerii*)
  - Arnica (*Arnica cordifolia*)
  - Aster (*Aster conspicuous*)
  - Big huckleberry (*Vaccinium membranaceum*)
  - Low huckleberry (*Vaccinium scoparium*)
  - Spiraea (*Spiraea lucida* and *S. splendens*)
  - Twinberry (*Lonicera utahensis*)

C. White pine, cedar, hemlock, and white fir zone:
  - Unimportant for grazing of domestic stock

D. Larch-Douglas fir zone:
  - Unimportant for grazing of domestic stock

E. Alpine fir—whitebark pine zone:
  - Redtop (*Agrostis* spp.)
  - Mountain brome (*Bromus marginatus*)
  - Idaho fescue (*Festuca idahoensis*)
  - Elkgrass (*Carex geyerii*)
  - Wiregrass (*Luzula* spp.)
  - Aster (*Aster* spp.)
  - Beargrass (*Xerophyllum tenax*)
  - Bluebell (*Mertensia* spp.)
  - Lupine (*Lupinus* spp.)
  - Labrador tea (*Ledum glandulosum*)
  - Mountain heath (*Phyllodoce empetriformis*)

Within the above forest types occur numerous dry meadows (Fig. 34) dominated by Idaho fescue, needlegrass (*Stipa*), redtop (*Agrostis*), sedge (*Carex*), oatgrass (*Danthonia*), and wheatgrass (16). Most of the forage is produced in open timber stands rather than under the dense timber, which often is too dense to permit of a great amount of herbaceous growth. The lodgepole pine forests, especially, are notably lacking in forage species.

Like other coniferous-forest types in the Rocky Mountains, these northern forests are used by both cattle and sheep and are grazed, almost without exception, during the summer only.

The Northwestern Coniferous Forest

The coniferous-forest region of the Northwest, including western Oregon and Washington and northern California, is the most important timber area of America and, except on the more open marginal areas, is distinctly more important for timber production than for grazing.

The northwestern forests thrive under a considerably higher precipitation than occurs in the Rocky Mountain forests, annual totals frequently exceeding 100 inches and being 50 inches or more over most of the area.

The temperatures generally are mild. Only the high mountains are characterized by low temperature and high snowfall.

Natural Vegetation. The northwestern coniferous forest has a great variety of vegetation, both tree and understory. The more humid coastal forests produce very dense stands of timber with little undergrowth other than the most tolerant species, such as ferns (Fig. 35). On dry lower slopes the forest is more open; hence, undergrowth is more abundant.

Coastal forests, having little undergrowth, are not important as ranges, and, aside from certain logged and burned areas that have been

FIG. 34. Dry meadow lands in the Blue Mountains of Oregon support many grazing animals during the summer season.

seeded to pastures and certain incidental uses, mostly as summer sheep range, they are not grazed. The lower mountain slopes and alpine meadows and parks on the upper mountains are grazed by sheep and also cattle; but generally they are low in capacity and should be grazed only so long as grazing does not interfere with the much more important production of timber.

Important among the many coniferous species of the Sierra Nevada are the following:

Abies concolor	*Pinus contorta*
Abies magnifica	*Pinus jeffreyi*
Abies nobilis	*Pinus lambertiana*
Libocedrus decurrens	*Pinus ponderosa*
Picea engelmannii	*Pseudotsuga taxifolia*
Pinus balfouriana	*Tsuga mertensiana*

In the great coastal forests the following conifers are important:

Picea sitchensis	*Tsuga heterophylla*
Pseudotsuga taxifolia	*Sequoia sempervirens*
Thuja plicata	

Many logged and burned forests in the Northwest have reverted to chaparral, which occasionally furnishes grazing where the brush is not too

FIG. 35. The northwestern coniferous forests are the finest timberlands in America and generally do not produce sufficient forage to merit grazing.

dense. These areas are dominated in California and parts of Oregon by species of *Ceanothus*, *Arctostaphylos*, *Myrica*, *Quercus*, *Arbutus*, *Prunus*, and *Rhamnus* (25). *Ceanothus integerrimus* is much the most important forage species. Farther north, species of *Salix*, *Alnus*, and *Acer* are important, and occasionally *Sambucus*, *Corylus*, and *Betula*. Many grasses and forbs occur as an understory to the chaparral where it is not too dense. Seeding burned forest immediately after the fire gives excellent results (Fig. 141, page 385).

Under the more open coniferous trees of the Northwest occur various forage plants, such as *Poa*, *Carex*, *Festuca*, *Bromus*, *Melica*, *Deschampsia*, *Agrostis*, *Lupinus*, *Vicia*, and *Lathyrus*, that furnish valuable feed to livestock.

The Southeast

Rapid developments have occurred in agriculture of the southeastern United States in recent years (24). This area extends from the Atlantic Ocean to about 96° west longitude and from the Gulf of Mexico to about

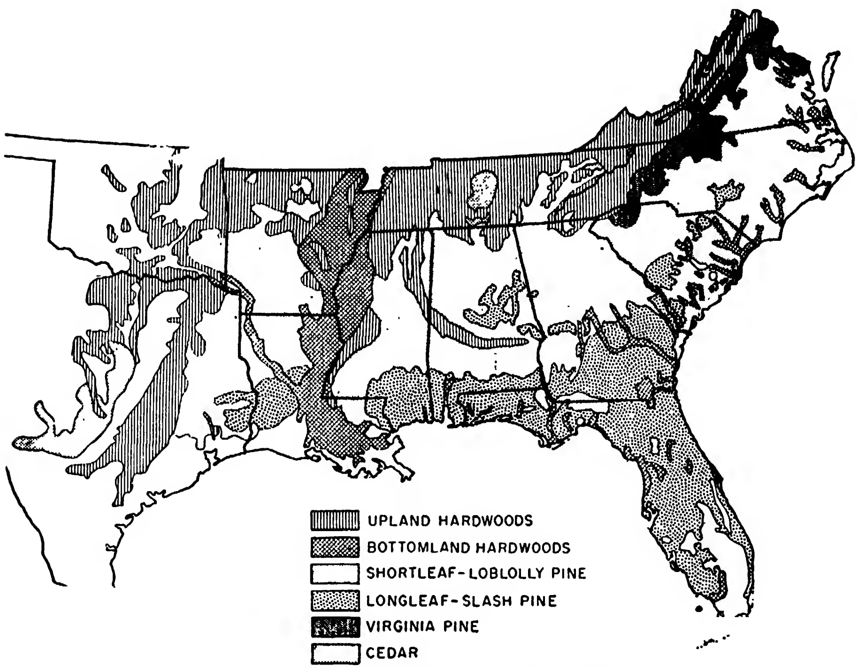

Fig. 36. Forest grazing types of southeastern United States. (*Courtesy of R. S. Campbell.*)

37° north. With an average of over 50 inches of rainfall and with 200 to 365 days of frost-free weather, vegetation growing potential is high. Heavily leached acid soils are the limiting factor. Nearly 200 million acres of forested range is grazed. Nutritious forage is available from native grasses for only about 3 months in spring and a few weeks in autumn. Protein and phosphorus are especially deficient (6). Heavy dependence upon supplemental pasture and feeds is, therefore, necessary. Decades of localized close grazing and frequent burning have changed natural vegetation greatly.

Most of the area is dominated by longleaf pine (*Pinus palustris*), slash pine (*P. elliottii*), shortleaf pine (*P. echinata*), loblolly pine (*P. taeda*), and

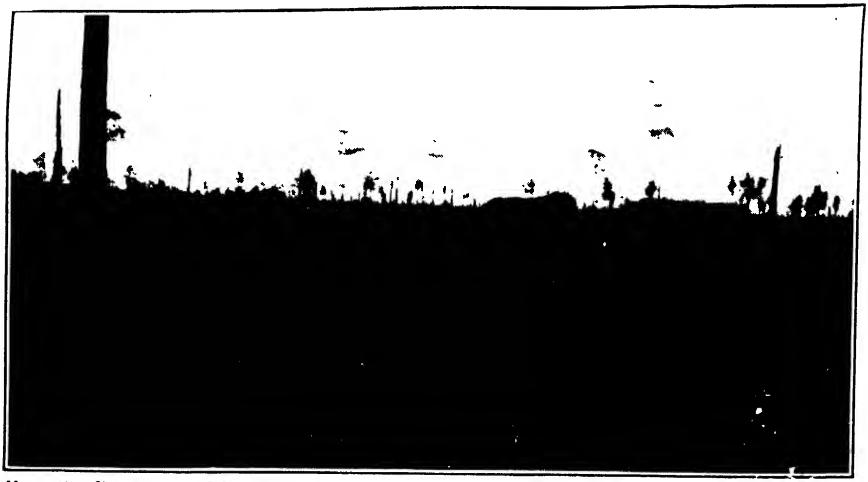

FIG. 37. Cutover and burned longleaf pine lands in Louisiana furnish forage to large numbers of cattle.

FIG. 38. Grade cattle grazing slash pine plantation in Louisiana. (*Photograph courtesy of U.S. Forest Service.*)

mixed hardwoods (Fig. 36). Open and cutover forests produce abundant forage (Figs. 37 and 38), but dense stands are almost worthless as grazing. Many coastal-plain areas are unforested and produce a wealth of grasses which with good management are productive ranges.

The South can be divided into three areas: the Coastal Plain, the Piedmont Plateau, and the Mountain region (24). A fourth area some-

times is recognized, namely, the bottomland hardwoods in the Mississippi River Delta and other river bottoms (Fig. 36).

The place of grazing varies considerably in these areas. It has limited place in upland hardwoods and in shortleaf–loblolly pine types where low grazing value does not justify the risks of damage to tree reproduction (21).

The lower Coastal Plain, mostly longleaf and slash pine, is far the most important of the southern areas for grazing. It includes low plains and rolling hills mainly in open forest. Principal range types are the wiregrass in the southeast, bluestem in the west Gulf coast, and scattered switch-cane and bottomland grass and shrub. A sizable area of coastal prairie and marshgrass occurs along coasts of Florida, Louisiana, and eastern Texas (5). Grasses include bluestem or broomsedge (*Andropogon*), *Panicum*, carpetgrass (*Axonopus affinis*), Curtiss dropseed (*Sporobolus curtissii*), threeawn (*Aristida*), *Paspalum*, muhly (*Muhlenbergia*), and Bermuda grass (*Cynodon dactylon*). The wiregrass type is the most important grazing type in the Southeast. Frequent burning has created this wiry, fire-tolerant, bunchgrass type (24); and periodic prescribed burning generally is recommended. This appears to be necessary to make efficient grazing use of the range. Winter burning increases spring cattle gains two- to threefold (7). Bluestem ranges in pine and upland hardwood forests of Mississippi, Louisiana, Arkansas, and eastern Oklahoma and Texas contain numerous species of *Andropogon* which furnish most of the forage. *Lespedeza* is locally important. Wiregrass ranges support 1 cow for 6 months on each 7.5 to 30 acres, whereas bluestem areas are slightly less productive (6).

The Piedmont is largely intermixed hardwood and pine forest. Only the pine forests are recommended for grazing. Broomsedge and other grasses and sedges are important forage. Honeysuckle (*Lonicera japonica*) is relished by cattle (7).

Mountain lands are predominantly forest. Grazing hardwood forest lands generally is not recommended because forage values are low and, unless carefully regulated, grazing reduces forest production so as to become uneconomical.

Bottomlands of the Mississippi Delta and swamps of Virginia and the Carolinas contain numerous openings in the hardwood forests which are dominated by a tall reed of the bamboo tribe, switch cane (*Arundinaria tecta*), which forms the best native range in the South. Switch cane is also of foremost importance in the North Carolina coastal-plain forest ranges (4). Grazing capacity varies from almost nothing in densely forested areas to as high as 5 acres per cow for the 6-month grazing season (6).

Throughout this region, cattle are important range users. Hogs abound in the area but frequently cause serious damage by rooting up longleaf

pine seedlings. Hogs, however, are a considerable source of income, and they do little damage on hardwood forests (7). Although sheep are nowhere of primary importance, they also damage pine reproduction by nipping the buds. Grazing is second to timber production as a land use, with the exception of unforested prairies, generally close to the Gulf coast. The potential of grazing, however, is just being realized, and use and production from these lands can be expected to increase greatly with improved management (21).

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CHAPTER 4

PLANT PHYSIOLOGY IN RELATION TO GRAZING

The individual plant is the foundation of the range. Range livestock are a product of plant growth, and meat production is commensurate with welfare of the plant.

Plant growth is controlled by such habitat factors as soil, moisture, and temperature. But it must always be remembered that growth results directly from food or energy supply. Virtually all plant energy arises from the air through the process of photosynthesis. Leaf surface, in turn, determines the quantity of carbon dioxide absorbed by the leaf and the quantity of sunlight energy available to the plant. Reduction of leaf surface by grazing reduces also the growth and productivity of the plant.

Obviously, therefore, it is not always economically feasible to manage a range so as to obtain maximum growth of the plant. But unless near optimum conditions for growth are provided, serious sacrifice in livestock production may result. Plant requirements must be understood. A good range manager will build his management plan around the individual plant as a unit. As this plant thrives, so does the range thrive.

Ranchers generally understand the care and feed requirements of livestock for maximum growth and reproduction. They know that fat stock are impossible without adequate food. It is essential to good range management that the rancher appreciates his role as a grassgrower. Healthy or "fat" grass results only from adequate food supplies. This principle applies both to herbage production and to seed and vegetative reproduction. The concept is basic to good range management.

It is fortunate for humanity that the plant is so efficient and versatile. One cannot study plants without being impressed by the precision of their physiological activity, the versatility of their adjustment to new conditions, their adaptation to withstand adversities, and the tenacity with which they cling to life, struggling against unfavorable climate, invading and competing plants, and animals that consume their foliage. The plant is a truly wonderful machine, and, given an opportunity, it serves as an unsurpassed and untiring benefactor to humanity.

FOOD SYNTHESIS OF PLANTS

Perhaps nothing is of more concern to the range manager than is food manufacture of the range plant and knowledge of how various systems of grazing influence that operation.

Green plants are the factory in which carbohydrates are manufactured from the raw materials of air and soil. Never has man duplicated, or even completely understood, the operations of these delicate factories. Yet, should they cease, man and all other life must ultimately perish.

Food manufacture is carried on mostly within the leaves. The plant leaf is made up of cells bearing green chlorophyll. Internal air spaces are connected to the atmosphere through numerous pores known as stomata, thus allowing free air circulation. It is from this air, and not from the soil, that the plant secures most of the materials used in producing its food. The carbon from the air and the water drawn from the soil are combined by the action of chlorophyll in the presence of sunshine to make a carbohydrate, probably a simple sugar.

Factors Influencing Synthesis. The manufacturing operations of the plant depend upon many factors, including (*a*) physiological efficiency of the plant, (*b*) amount of carbon dioxide in the air and the freedom with which it enters the leaf, (*c*) area of leaf surface, (*d*) intensity of light, (*e*) water supply, (*f*) temperature, and (*g*) soil nutrients.

The water available to a plant determines photosynthetic activity in two ways: it is a necessary chemical constituent for the reaction; and it serves to keep the plant turgid and the stomata open and functioning. Reduction in the rate of photosynthesis to 50 or even 25 per cent of the normal accompanies wilting of the foliage, and virtually complete cessation results from continued drought.

The area of leaf surface exposed, other factors being equal, determines the rate of food manufacture. The average rate of photosynthesis is between 0.8 and 1.8 grams of sugar per hour for each square meter of leaf, depending upon the species (18).

For storage, the food manufactured in the leaves is transported to the roots or in woody perennials to the stem and in annual plants to the seed. Most plants manufacture more food during the summer than is necessary for immediate respiration; hence, it is accumulated as a reserve. This food reserve, ultimately, is used (*a*) in reproduction and (*b*) in growth following winter or drought dormancy. These two functions are very important to range management, and it is essential that range plants be allowed to manufacture and store excess food during the summer.

REPRODUCTION OF PLANTS

Under normal conditions, native plants are lavish in their production of reproducing organs. Were all the seeds and specialized stems and roots of a single year to produce a new individual, there would be no space in which they could grow. Most plants, though not all, reproduce by seed. Many native range plants depend, in addition, upon specialized organs

developing from the stem or the root. Such methods which do not involve seed are known as *vegetative* reproduction. Vegetative means of reproduction are especially valuable to a range plant when heavy grazing restricts seed formation. However, heavy grazing, which weakens a plant, ultimately will prevent reproduction even by vegetative means. Among the reproducing methods exhibited by western plants are seed, rhizome, stolon, tiller, layering, corm, bulb, and adventitious budding.

Seeds. Seeding is the most usual method of reproduction among the higher plants and the sole method of many perennials and all annuals. Seed reproduction requires little food reserve and plants can produce seed despite serious adversity. Seeds are produced rapidly and may be scattered great distances in a short time by wind, water, or animals.

Seed reproduction has some disadvantages. The young plant is independent and must rely upon its own roots to supply moisture from the beginning of its active life. In drought years, the seed may fail to germinate or the young plant may be killed by drought before it can send its roots down to the permanently moist subsoils. In much of the West, precipitation is of the winter type and summers are dry. A seedling starting growth in the spring must send its roots into the ground with sufficient speed to keep below the ever-deepening layer of dry soil. This layer, with moisture below the wilting point of the plant, often reaches depths of 2 to 3 ft. The ability of the seedling to develop a deep root system in proportion to its aboveground parts frequently determines its success.

Seeds provide an efficient means of survival over drought periods, as in the case of annual plants in the hot and dry valleys of California and the deserts of Arizona. These plants spring to life when the rainy season arrives, rapidly mature seed, dry up, and die. The seed maintains its spark of life for many years and despite many adversities. Seeds of native plants are known to remain viable for periods of 5 or 10 years or even longer; survival of seeds after as long as 200 years has been observed. The specializations that plants have developed to protect, spread, and ensure the success of their seed are marvels of nature.

Rhizomes. Rhizomes are an important means of reproduction and are developed by perhaps one-third of the western range plants. These plants, often called *sod formers*, may produce few if any rhizomes under unfavorable growing conditions, whereas plants normally not considered sod formers may produce numerous, often short, rhizomes under unusually favorable circumstances.

A *rhizome* is an underground stem, as is evidenced by the presence of nodes and leaf scales. Rhizomes often spread many feet just under the surface of the soil, and young plants arise, sometimes from each node. Some vigorously growing plants produce rhizomes in such abundance as

to form a dense mat just below the soil surface and may become sod-bound and their foliage production is reduced.

The rhizome is valuable to range plants in that it is below ground and is seldom subjected to mechanical injury. Reproduction is possible, though physiologically restricted, under conditions of heavy overgrazing. Rhizomes, having a greater food reserve at their disposal than do seeds are able to produce new plants from great depths such as occur when blowing soil is deposited upon them. They are capable of adjusting their growth level to the changing surface level, turning up or down as the occasion demands. Rhizome reproduction is reliable in dry years, for the rhizome is attached to the mother plant and hence can draw moisture from the established roots. The resulting plant can grow and mature in a short time. In the invasion of densely vegetated areas, the rhizome proves more efficient than the seed because it can thrust its way into the dense vegetation where a seed would have great difficulty establishing itself. The rhizome has a disadvantage in that it is not mobile but generally remains close to the parent plant.

Other Methods of Reproduction. Other methods of vegetative reproduction generally are inferior to rhizomes. The *stolon*, or *runner*, though efficient, is rare in range plants. It is similar to the rhizome, except that it is an aboveground organ; in fact, some plants produce one or the other, depending upon soil conditions. An important stoloniferous forage plant is buffalo grass of the Great Plains, which has shown the stolon to be very effective where summer rains keep the surface soil moist during the growing season (Fig. 14).

Layering is a process common among mountain shrubs. It is similar to the stoloniferous method, except that the normal stem takes root where a node touches the ground.

Tillering is not unlike reproduction by rhizome or stolon, except that the stems are short rather than long and trailing. A tiller is a basal branch originating from the lower nodes of the stem. These branches grow outward for a short distance only and then turn up. This is a means of increasing area rather than of reproducing. However, over a period of years the older material may die, leaving an outer ring of living tillers which may later break up into individual plants.

Corms and *bulbs* are not primarily means of reproduction; rather, they are for the purpose of food storage, which takes place in enlarged stems in the corm and in enlarged basal leaves in the bulb. These organs are used by man in reproducing plants, such as the tulip and onion.

Bulbils are small aerial bulbs whose primary purpose is reproduction. The bulbil falls to the ground shortly after maturity and, much as a seed, it produces a new plant. The bulbil may grow in the axil of the leaf or in the flower head instead of seed, as in bulbous bluegrass (*Poa bulbosa*).

Adventitious budding from severed branches, sprouts from the mother stem, or shoots from the roots are methods of reproduction that are important among woody plants, especially trees such as the poplar and willow.

ROOT HABITS OF PLANTS

Roots, being underground, are not easily studied; yet on the range, where water is vital, there is no part of the plant more important. A knowledge of the anatomy and physiology of the root is elementary to the manager of the range, for its characteristics and operation determine to a great extent the ability of a plant to thrive.

The many studies of Weaver in the prairies and plains are of great importance to an understanding of the physiology and ecology of roots.

The underground parts of plants are layered much as the aboveground parts are, some plants rooting shallowly in the interstices between deeper-rooted plants and others possessing very deep taproots, which penetrate below the general level and form extensive networks there. Competition is dependent upon rooting habits. Plants rooting in the same zone compete more than do those in different zones, though surface moisture may be intercepted by shallow-rooted plants at the expense of deeper-rooted plants. In the short-grass plains, the surface moisture, which comes largely during the growing season, is absorbed by the shallow-rooted grasses, which can easily dominate over deeply-rooted forbs and shrubs. Conversely, in the Great Basin, where heavy snow results in deep percolation, the surface-rooting grasses do not compete so effectively with the deep taproots of shrubs and forbs.

The root system is important to winterkilling. Plants with deep roots are injured less than are shallow-rooted plants during cold weather, for they have access to moisture in the unfrozen subsoils and do not become desiccated (35).

Size of Root System. The root is the medium whereby the plant makes contact with the soil, and the leaf is the medium whereby the plant makes contact with the air. The plant is the connecting link, or exchange medium, and it controls only to a small degree the amount of water transported. If the air is so dry as to make urgent demand upon the water in the plant, and the soil so dry as to prohibit a sufficiently rapid replacement, then wilting and possibly death result. The rapidity of water loss and of absorption is proportionate to the size of the transpiring and absorbing organs. Most drought-resistant plants have large and deep root systems and small aboveground parts, though there are many exceptions, such as the cactus, which depend, not upon ability to secure water, but upon ability to hold water against the demands of the atmosphere.

Root branching and lateral spread are important, though perhaps less

so than root depth. Deep roots reach a moister soil, whereas the advantage of wide lateral spread is largely one of increased area of contact. Amazing results have been secured from studies of the absorptive area of roots. Pavlychenko (22) found that a three-year-old plant of crested wheatgrass had a total root length of 315.4 miles, bromegrass of 65.2 miles, and slender wheatgrass of 9.9 miles.

Dittmer has shown that a single winter rye plant supported over 13 million distinct root members with a total surface of 2,554 sq. ft. and a combined length of 387 miles (9). A root-hair surface of 4,321 sq. ft. was noted. The combined surface of roots and root hairs was found to be 130 times that of the aboveground parts.

Length of Root System. Measurements of root length or depth is seldom made, because of the time and careful work required. Spence (28) found fibrous-rooted annual plants to have few and short roots, as *Bromus tectorum* with only seven major roots, which penetrated only about 30 cm. Short-lived perennials had more abundant but, nevertheless, short roots. *Poa secunda*, as an example of the latter type, produced many roots, but they penetrated only to 40 cm. Long-lived plants such as *Agropyron inerme* and *Carex geyerii*, conversely, produced more than 200 major roots and penetrated about 160 cm.

Amazing root depths of common prairie plants were shown by studies of 43 representative species. Of these, 14 per cent absorbed almost entirely in the surface 2 ft., 21 per cent between 2 and 5 ft., and 65 per cent below 5 ft. Depths of 8 to 12 ft. are common, and maximums of over 20 ft. have been recorded (26). Cannon (5) reports a mesquite root in southern Arizona that penetrated to 8 m. and supported lateral roots 15 m. in length. By no means all desert plants, however, have extensive roots; many of the succulents, indeed, are unusually shallow-rooted. Certain species of cactus studied by Cannon did not root below 2 cm., though they had widely spreading root systems; and even the giant *Cereus* rooted to only 77 cm.

Studies (6) attempting to relate drought resistance among selections of smooth bromegrass with root depth and development showed that resistant strains were consistently high in numbers of roots and that their roots were significantly greater in depth. Total axial root length was the best single measure to drought resistance and in all cases correlated with proved field performance in drought resistance.

Roots as Soil Builders. Tremendous importance must be attached to roots as soil builders and soil binders. Studies on Nebraska prairie showed over 4½ tons dry weight of roots per acre under the best bluestem prairies. Grama-buffalo grass disclimaxes produced as high as 2⅓ tons (26). The roots add organic material to soil at a rapid rate and to depths of 10 ft. or more. Studies on length of life of grass roots (36) indicate that

relatively rapid replacement is usual; hence organic matter is constantly added to the soil. No roots of some species (*Elymus canadensis*) lived over 3 years, and in other species, 10 per cent (*Andropogon scoparius*) to 45 per cent (*Bouteloua gracilis*) survived 3 years. Clipping to simulate grazing increased death loss in roots of *Agropyron cristatum* from 3 to 73 per cent.

EFFECT OF GRAZING UPON PRODUCTION OF THE PLANT

Disuse is not normal for vegetation. From time immemorial, vegetation has furnished food to animal life of all descriptions. Only abnormal use has resulted in widespread destruction. Unusual accumulations of insects, rodents, or big-game animals may destroy plants, and unwise grazing by stock has accounted for much vegetation loss. However, normal use of a plant will not cause it undue injury. Presumably nature has given most plants a margin of safety which permits them to function at near-normal levels with occasional grazing and generally to survive for long periods despite severe mutilation. Indeed, ungrazed Nebraska prairie has been shown to produce less herbage than comparable grazed prairie (37). Fifteen years without grazing or fire resulted in a deep mulch which promoted infiltration and reduced evaporation. Lower soil temperature under the mulch delayed spring growth 3 weeks and herbage yields were from 26 to 57 per cent less than those of the grazed prairie.

Relationship of Life Form and Grazing Damage. Removal of the terminal bud from the stem of a forb or shrub stimulates the development of one or more lateral buds, the branches from which become the main stem. It is not to be presumed that this is harmless, for a temporary lapse in growth rate is inevitable. For grazing, however, a limited amount of such use may be desirable, for it tends to make the plant less rank and more bushy and leafy (Fig. 39). However, heavy use of woody plants may result in a maze of branches from which the animal can obtain the leaves only with difficulty.

The terminal bud of grasses remains near the ground surface until shortly before flowering, at which time the bud of flowering stems is sent rapidly upward. Sterile or nonflowering stems, producing more leaves than flowering stems, may make up 50 to 90 per cent of the total stem numbers, depending upon species and environment. Such stems are elongated little if any in some species, whereas in others the bud or growing point is elevated to considerable distance aboveground. It has been suggested that grasses whose buds remain near, or even below, the soil surface are much less susceptible to grazing injury than are those species which elongate the barren as well as the flowering stems (4).

When the bud of a grass stem is removed by grazing, no further devel-

opment or elongation of the shoot takes place. Buds at the base of the stem are stimulated; hence, new shoots grow and replace the original stem (7), provided soil moisture remains favorable.

The meristematic tissue of the grass leaf is at the sheath base and collar. However, as soon as the leaves are free of the enclosing sheath and the blade has unrolled, the meristem apparently becomes inactive for that particular leaf, and growth ceases. A leaf cut or grazed after it is fully emerged from the sheath of the next-lower leaf actually will not grow or

FIG. 39. Bitterbrush (*Purshia tridentata*), under heavy grazing, shows the abnormal branching tendency induced by frequent removal of the growing tip. This hedged appearance is an early response to excess grazing.

develop. Thus, the grass leaf behaves very like the leaf of a forb or shrub following grazing.

An unelongated grass shoot grazed to a point just above the growing bud may have most of the leaf blades removed but the stem will continue to elongate. The blades will not regrow; hence the plant is composed almost wholly of stems (Fig. 40). Basal buds will not be stimulated; hence no new leaves are produced, and the plant is low in both palatability and nutritive value. Closer grazing is necessary to stimulate basal bud development for new leaf growth.

Like the forb and shrub, grass when close-grazed is stimulated to produce lateral branches at its basal nodes. Many authorities contend that a

thicker sod growth is obtained with grazing, but these observations are limited to areas of good fertility and soil moisture. It is quite possible that the lateral branching stimulated by grazing results in a thickened stand. Certainly a well-watered and fertilized lawn is damaged but little by its weekly clipping, provided that it is not too closely cropped, and it

FIG. 40. Leafless crested wheatgrass culms (right) resulted from close grazing when the grass was in the 3d-leaf stage and stems were not elongated. This stem regrowth will occur whenever the topmost node of the stem is not removed. Ungrazed culm is shown on left. [*After Cook and Stoddart* (7).]

becomes finer and more succulent than unclipped plants. More nourishing and less fibrous forage is obtained by frequent harvesting, even though a lessened yield may be incurred.

Physiology of the Plant Influenced by Grazing. Man knows little of how much grazing use a plant can withstand without undue injury—knowledge, surely, that is basic to proper range management. The object of range management is the obtaining of maximum forage consistent with

perpetuation of the vegetation. It is important, then, to know how grazing influences the functions of the plant and just how much they may be disturbed without permanent injury.

Grazing is especially detrimental (*a*) in early spring when excessively wet soil results in trampling damage, (*b*) in seasons when root reserves are low or when plants are unable to replace leafage because of dry weather, and (*c*) when continued at a frequency or intensity which does not allow adequate photosynthetic tissue to remain on the plant.

The effect of these factors upon the plant differs greatly with different species, but certain principles common to all should be understood before attempting to judge proper range use.

Husbandmen long ago learned that animals work inefficiently unless they are properly fed and cared for. This conception has not, however, been extended to plant life. If appreciation of plants as growing organisms had been widespread, much injury to range lands might have been avoided. Plants are living organisms, fundamentally not unlike animals, growing, breathing, digesting, and dying. If too great demands are made upon them, premature death occurs. They require definite conditions for their proper development. Any grazing use which prevents such development constitutes misuse of the range and will result in decline of forage production.

Relation of Season of Grazing to Food Synthesis. The plant grows at a rapid rate in spring when warm temperatures and generally abundant soil moisture permit. Such growth is initiated by use of stored food reserves in the plant, generally in the root. Approximately 75 per cent of these reserves are used in the spring to produce some 10 per cent of herbage growth, subsequent growth being dependent upon current food synthesis (17). Heavy demand is made upon the newly manufactured food reserves as fruits and seeds are formed. These grow rapidly and they are concentrated storage organs; hence their growth requires large food supplies. Following this period of active growth and seed production, there is a period during which the plant stores reserve food (Fig. 41). This storage may occur after the herbage is seemingly inactive. The reserve food in the perennial plant provides it with material with which to initiate growth the following spring.

The cyclic functions of a plant and cycles of weather are important in determining growth rate. Depressions in growth rate coincide with dry or cold weather and with the advents of flowering and fruit formation. Food storage also is cyclic. Reserves are at a minimum during periods of greatest growth and reach a maximum during late autumn (17).

Knowledge of minimum-food-storage periods is important, for, when food supply is low, forage plants are most subject to damage from grazing, and undesirable plants are most easily killed by mowing or spraying. In

snowberry (*Symphoricarpos*) positive correlation was found between food reserves in the roots and reaction of the brush to mowing (1). Mowing resulted in root sprouting, which increased stalk numbers when reserves were high, but stalks were reduced by mowing when food reserves were low. Eradication resulted from three annual cuttings at periods of low food reserves.

Mountain grasses were harmed least by clipping in early growth (4- to 6-inch height) or at the end of the growing season when foliage was dry (17). Storage was 90 and 88 per cent, respectively, of normal under these

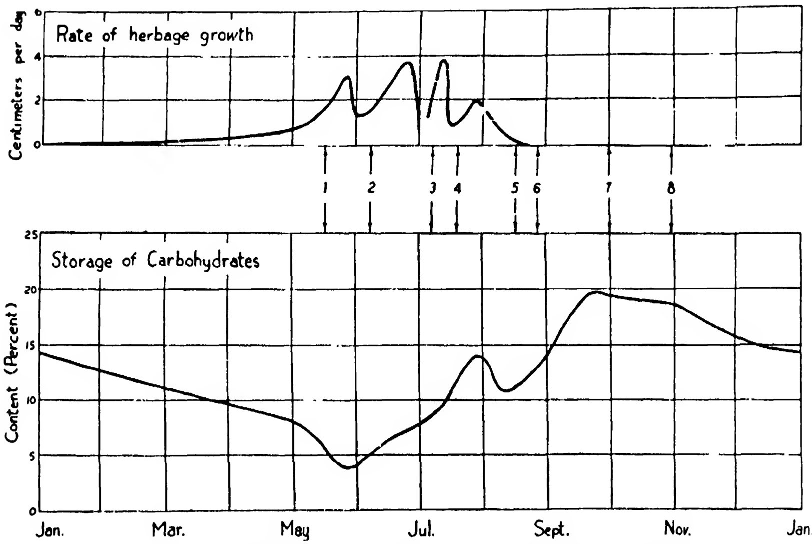

FIG. 41. Annual herbage growth of mountain bromegrass in high Wasatch Mountains of Utah in relation to total sugar and starch storage in the root and stem base. Point 1 = date of snow disappearance in spring, 2 = flower stalks in evidence, 3 = flower heads fully out, 4 = flowers in bloom, 5 = seeds fully ripe, 6 = seeds dropping, 7 = seed entirely dropped, and 8 = snow cover in fall. [*Data from McCarty and Price* (17).]

two conditions. Lowest storage (67 per cent) occurred when plants were clipped at the time of seed ripening.

In areas of dry summers (generally west of the Rocky Mountains), time of cessation of grazing may be more important to plant welfare than time of beginning grazing (31). Late grazing removes herbage and prevents regrowth prior to the time the rainless period brings the growing season to a close. Such plants have no leaves for food manufacture and cannot grow new leaves. Therefore they cannot replenish food reserves prior to the following spring. Early-spring growth must be made with insufficient root reserves; hence decline in plant health is inevitable.

Studies on bunch wheatgrass showed that two years of close clipping

at biweekly intervals, from Apr. 15 to June 15, will kill this climax bunchgrass (Table 17).

TABLE 17. EFFECT OF CLIPPING UPON HERBAGE YIELD AND SURVIVAL OF *Agropyron spicatum*
Yields are expressed in per cent of original (1943) yield
Data from Stoddart (31)

Clipping conditions	Percentage total annual yield was of original yield		Percentage of original plants alive fall of 1945
	1944	1945	
Clipped at 1-inch height:			
Weekly, Apr. 15–May 7	41.34	20.49	100
Weekly, May 1–May 22	23.48	1.24	25
Weekly, May 15–June 7	40.95	4.25	50
Weekly, June 1–June 22	79.00	6.91	55
Biweekly, Apr. 15–May 15	35.03	11.41	75
Biweekly, May 15–June 15	45.13	2.99	20
Biweekly, Apr. 15–June 15	30.36	.37	0
Biweekly, Sept. 15–Nov. 1	128.41	88.02	100
Clipped at 2-inch height:			
Weekly, Apr. 15–May 7	53.54	40.17	100
Weekly, May 1–May 22	38.80	9.93	90
Weekly, May 15–June 7	49.89	7.48	50
Weekly June 1–June 22	70.30	8.53	75
Biweekly, Apr. 15–May 15	76.67	39.75	100
Biweekly, May 15–June 15	46.92	5.04	35
Biweekly, Apr. 15–June 15	37.20	3.35	45
Biweekly, Sept. 15–Nov. 1	109.18	73.21	100

Critical periods in the life cycle of forage grasses appear to be (*a*) the period of active reproduction, from flower-stalk formation to and including seed ripening, and (*b*) the forepart of the normal carbohydrate storage period (17). Although this latter period occurs in August and September in Utah mountains (Fig. 41), it likely occurs earlier on hotter and drier ranges. It must be kept in mind that grazing injury may be associated more with soil moisture and opportunities for regrowth than with physiological stage of development (3).

Almost without exception, experiments have shown total herbage yields from arid ranges to decrease with increased frequency of clipping during any one year, and with closer harvesting as compared with clipping 3 to 4 inches from the ground. Exceptions to this rule are limited to more favorable habitats where soil and moisture relationships are such as to

encourage growth despite frequent herbage removal. Bluegrass pastures, for example, appear to form a thick and productive turf with frequent grazing, which stimulates tillering from the basal nodes of grazed stems.

Although a single harvesting at the end of the growing season usually produces the greatest yield possible under dry-range conditions, there are exceptions to this. Several experiments have indicated that plants in summer-rainfall areas are stimulated by herbage removal to renew growth and produce increased total herbage yields. Such appears to be the case with buffalo grass and blue grama in the Great Plains (16, 34), which are noted for their ability to respond quickly to favorable growing conditions. Mid-grasses, however, did not respond in the same manner (Table 18).

TABLE 18. FORAGE YIELDS IN WYOMING UNDER FREQUENT HARVESTING COMPARED TO SINGLE HARVESTING, IN POUNDS PER ACRE

Data from Lang and Barnes (16)

Clipping dates	Mid-grasses	Short grasses	Forbs
Frequently clipped:			
June 4	696.2	122.5	156.1
June 27	66.9	96.0	26.4
July 22	85.0	91.2	11.0
Aug. 23	21.9	50.4	15.1
Oct. 20	12.2	0.0	0.0
Total	882.2	360.1	208.6
End of growing season only:			
Oct. 20	1,564.1	273.7	69.6

Browse plants completely defoliated three or four times in a season are readily killed, and removal of only half of the foliage markedly weakens the plant (25). However, shrub species studied on Oregon and Washington winter game ranges were stimulated to greater productivity when many or all twig ends were cut off once a year, but clipping stimulated twig growth at the expense of flower and fruit production. Remarkable production was obtained from heavily clipped shrubs (12). On winter ranges, bitterbrush production was maintained under use of 50 to 60 per cent, curlleaf mountain mahogany under use of 50 to 60 per cent, and ceanothus under 35 to 40 per cent. For further information on season of grazing see Chap. 13, page 317.

Quality of Forage as Affected by Clipping. More important than total herbage yield is the actual digestible nutrient yield from the range. Chemical composition and digestibility of herbage differ radically according to species, soil, season of the year, and other factors (see Chap. 11). The value of forage varies also with the frequency of harvesting. For example, frequent harvesting may be followed by a regrowth of forage of high pro-

tein content and relatively low fiber. Even though herbage yield declines with frequent harvesting, total protein yield may increase because of increased percentage (Table 19).

TABLE 19. TOTAL YIELD AND PROTEIN YIELD OF PASTURES CUT AT VARIOUS PERIODS DURING THE SEASON
Data from Ellett and Carrier (10)

Frequency of cutting	Air-dry yield, pounds	Average protein content, per cent	Total protein yield, pounds
Every 7 days	111.34	15.58	17.36
Every 10 days	112.93	14.84	16.76
Every 20 days	114.93	14.43	16.58
Every 30 days	138.45	12.67	17.93
Once a year	197.25	8.25	16.28

Forage regrowth from frequently harvested plants is more leafy and generally is more palatable to livestock because it is more tender, higher in moisture content, and contains less yellowed and dried material. This leads to the conclusion that moderately heavy grazing during the growing season is desirable up to the limit of the capacity of the plants.

The above observations do not imply that heavy range use necessarily improves forage quality. Actually, the closer stock graze a range, the poorer quality of forage they receive, unless conditions are favorable for rapid regrowth. On winter sheep range (8), it was found that as the degree of utilization of shrub ranges during the nongrowing season increased, the content of the more desirable nutrients in the available forage decreased, and, in addition, the digestibility of these nutrients was decidedly lowered. Thus, with heavier utilization, the animals were forced to consume the less nutritious portions of the shrubs, and as a result the available nutrients frequently were not adequate to meet the demands of the grazing animals.

Relation of Herbage Removal to Root Growth. By reducing the photosynthetic area through grazing, food manufacture is reduced, and there is a consequent reduction of the material available to the roots. The reaction of roots to clipping is both immediate and marked, as shown by the work of Parker and Sampson (21), in which a single harvesting of foliage resulted in temporary cessation of root growth in grasses and was followed by immediate transfer of growth to the tops. So sensitive were the plants that a single harvesting at any time during a 120-day test resulted in a decrease in the root yield, the greatest decrease resulting during the periods of most rapid growth.

Robertson (23) noted reductions in the length of roots of grasses following frequent clipping, to one-fifth of normal, an almost insurmountable handicap to a plant in an arid region. Other studies have shown that individual roots may be smaller and the production of rhizomes inhibited through heavy clippings (2).

Both the frequency and the height of clippings influence yield of roots (Table 20).

TABLE 20. EFFECT OF HEIGHT OF CLIPPING UPON WEIGHT OF ROOTS: PLANTS CLIPPED 16 TIMES AT 5-DAY INTERVALS

Data from Harrison (15)

Height of cutting, inches	Root weights, grams		
	Red fescue	Blue-grass	Colonial bent
¼	1.4	1.6	2.1
1½	8.6	7.5	5.0
3	13.7	11.7	7.7

Black grama, blue grama, and galletagrass (*Hilaria jamesii*) excavated from properly grazed, overgrazed, and heavily overgrazed ranges had root systems reaching depths of over 4 ft., slightly over 2 ft., and less than 1 ft., respectively (11). The short root systems resulting from overgrazing supported only scattered clumps of grass, and there was not sufficient water-storage capacity within the absorbing zone of the restricted root system to maintain the grass through protracted drought periods.

Comparable conditions have been observed in the case of *Agropyron spicatum*, the roots on overused ranges penetrating only 44 cm., whereas on protected ranges they penetrated over 65 cm. (14).

Range Management Based on Physiology of the Plant. Any grazing, whether moderate or heavy and whether early or late, has a measurable influence upon the metabolism of a plant. With reduction of photosynthetic tissue comes reduction in carbohydrate and nitrogen reserves and decreased rate of root and forage production. The acceptance of this fact is basic to range management. Provided that grazing is neither too frequent nor too close, it is quite possible that the total forage value may not be decreased greatly; for, despite the fact that a lesser volume is produced, it sometimes is of better quality because grazing may stimulate leafy regrowth.

Vital to the range plant is the influence of grazing upon volume and depth of the root system. A reduction of food reserves slows the growth of the entire plant, and root growth is not excepted (Fig. 42). This is one of

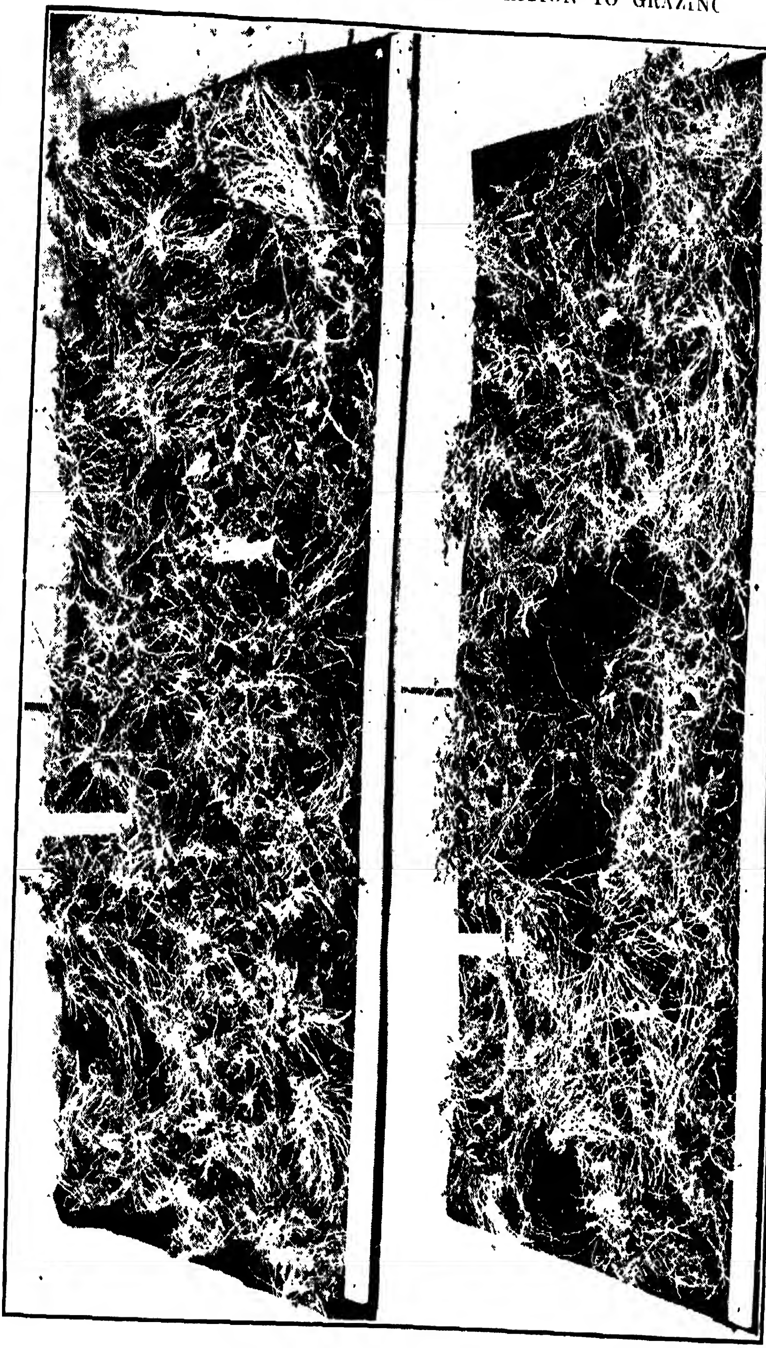

FIG. 42. Underground parts of big bluestem (*Andropogon gerardi*) from adjacent areas. The upper were washed from 1/2 sq. m. of soil from an undisturbed prairie, whereas the lower were washed from an area closely grazed for 2 years. The roots are in their natural position. (*Photograph by J. E. Weaver.*)

the most important effects of incorrect grazing. Many ranchers attribute decline of range production during the decade 1930–1940 to abnormal drought. There can be no question that drought did great damage and that it would have caused a decline in forage production despite good management of the range. Likewise, there can be no question that damage was far greater than would have occurred had the plants been in a normal condition. Strong plants, like strong animals, can withstand much more punishment than can the weak.

Water must be drawn to the root from the soil through a complicated and slow process of absorption and osmosis; and where transpiration is rapid, wilting may occur, even with a relative abundance of soil moisture, because of the slow movement. Only by a widespread root system can sufficient water be obtained to maintain turgidity of plant cells during periods of stress.

When surface soil becomes dry, absorption in the upper layers is impossible, sometimes to depths of 3 ft. or more. Here, a deep root system is essential. No amount of surface roots will enable the plant to live in these dry soils. Deep soil layers are usually moist; if the plant can tap this source of water, its chance of survival is infinitely greater. Plants that have been heavily used by livestock are injured more easily by drought because of their inability to reach deep moisture.

EFFECT OF GRAZING UPON REPRODUCTION OF THE PLANT

Decrease in valuable forage plants on the range results, not entirely from the death of established plants, but also from a decrease in reproduction and consequently a smaller number of young plants available to replace normal death losses of older plants. The life span of a range plant varies from a few weeks in annuals to 50 or more years in shrubs and, possibly, in perennial grasses also. Many perennials reproduce, not each year but, rather, each 5 or 10 years when ideal combinations of weather result in free pollination of flowers and formation of seeds and when a good year for seedling establishment follows. Often no seedlings of the forage plants will be in evidence, but the range manager need be concerned about this only when it is an abnormality and not a normal interval between the so-called good years. When it becomes evident that mature plants are not being replaced by young plants, maintenance of the range depends upon an immediate change in livestock management to allow normal reproduction.

Studies of Utah deserts (29) on heavily grazed areas showed that desirable climax woody plants averaged much older than did the less valuable invading species. Thus, 43 per cent of the rabbitbrush (*Chrysothamnus*) was less than 10 years old whereas none of the much preferred winterfat

(*Eurotia*) was less than 10 years old. The ratio of dead to living plants of rabbitbrush was less than 10 per cent; whereas that of winterfat in heavily grazed pure types was 59 per cent, as compared with 23 per cent on adjacent moderately used ranges. Indian ricegrass (*Oryzopsis*) studied on these two areas showed about 90 per cent of the plants to be dead on heavily grazed range and only about 24 per cent on moderately grazed.

Relation of Grazing to Seed Production. The influence of grazing upon seed production is twofold. The animals may graze the plant so heavily as to consume the seedstalks prior to the dropping of seed, or they may so disturb the physiology of the plant as to prohibit seed formation. Probably the latter is far more important than the first, despite the general opinion to the contrary. Many references to deferred grazing stress deferment until seed formation as though that were the primary purpose of deferment. Actually the production of seed probably is a minor benefit accruing from deferment, whereas the allowance of normal early-season food storage is a major benefit.

Very heavy grazing would be necessary to consume all the seed produced by healthy plants. Because nature is so lavish with the number produced, the seed remaining after the usual grazing may produce all the young plants for which there is space. Some plants so protect their seeds as to make them inaccessible to ordinary grazing; on others, they are easily accessible and highly preferred.

Since seed formation requires large quantities of concentrated food reserve, any depletion in the reserve of the plant interferes with normal seed formation. Unfortunately, few studies have been made of this very important phase of range management, but observation and research substantiate this theory.

The work of Hanson and Stoddart (14) showed that the seed of wheatgrass (*Agropyron inerme*) on improperly grazed range and that on correctly grazed range were of comparable vitality. Other studies on wheatgrass that had been artificially harvested at various intensities for 4 years showed no significant difference in the germination of filled seeds from clipped and unclipped plants.

A strikingly different picture is shown when the volume of seed production is considered (14). Lightly grazed stands of wheatgrass, compared with a heavily grazed stand, showed almost 17 times as many seed heads, which, in turn, produced over 50 times as many viable seeds (Table 21).

In Oregon, decreased vigor of the plant induced by grazing not only reduced seed production and germination but also influenced the season of seeding (24). Overgrazed ranges produced seedstalks 4 to 7 days later in the spring and also required a period 6 to 10 days longer for completing seeding. Clipping experiments showed the production of forage and seed to be unaffected by fall grazing, however.

TABLE 21. SEED HEADS, FILLED FLORETS, PERCENTAGE GERMINATION, AND VIABLE SEEDS PRODUCED ON GRAZED AND PROTECTED STANDS OF *Agropyron inerme*
Data from Hanson and Stoddart (14)

Condition	Number of heads per square meter	Filled florets		Germination (filled florets)	Number of viable seeds per square meter
		Per square meter	Percentage		
Grazed.......	7.1	19.6	23.9	62.2	12.2
Protected.....	120.4	972.6	38.8	64.8	630.2

Influence of Grazing upon Vegetative Reproduction. Many of the vegetative organs, especially rhizomes, bulbs, and corms, serve in food storage, reproduction often being secondary. These organs are of small size or are even entirely absent in instances where synthesis of food is curtailed. The reaction of Johnson grass to clipping (Table 22) indicates that frequent and early clippings are most detrimental to rhizome production. Also, close clipping is more detrimental than less close (15).

TABLE 22. RHIZOME YIELD OF JOHNSON GRASS CUT AT VARIOUS GROWTH STAGES
Data from Sturkie (32)

Stage of cutting (plants were cut each time they reached designated stage)	Weight of rhizomes, grams				
	Cut continuously		Permitted to grow a crop of seed before cutting in 1927		Permitted to grow a year before cutting
	1927	1928	1927	1928	1928
1 ft. high...............	130	10	658	11	45
2 ft. high...............	262	51	608	75	110
Booting................	321	139	604	74	383
Blooming...............	408	181	772	191	479
Late milk...............	589	495	811	345	799
Seed maturity..........	774	739	.....	...	802
End of growing season...	1,180	1,281	1,180	1,281	....

Rhizomes of *Hilaria jamesii* in the Southwest were found to average 6 ft. in length when the plants were not impaired by heavy grazing; but when the plants were heavily grazed, rhizomes did not develop beyond a few inches in length, the grass being thus restricted to a bunchlike form much less efficient for erosion prevention (11).

OTHER INFLUENCES OF GRAZING UPON VEGETATION

Grazing animals have an influence upon the soil, tending to compact it to surprising depths, especially during the spring or other moist seasons. Not only are compact soils poor absorbers of precipitation, but they prohibit normal root development, the roots sometimes being only half their normal length. Compaction is greatest near the surface and is of considerable influence in making the soil hard and unfit for seedlings to become established. Conversely, when the soil is not wet, animals are believed to be beneficial in loosening the soil surface and covering seeds that have accumulated on the surface. In line with this theory, a herd of sheep often is passed over an area, after or before broadcast seeding, to loosen the soil and cover the seed.

The mechanical action of animals in loosening seed, in carrying burs, awned seeds, and the like, in their hair, in distribution of hard-coated seeds through the fe[illegible], and in loosening bulbs, corms, and bits of rhizome that they may be transported elsewhere is probably of unsuspected importance. There are instances in which total protection of range from livestock has failed to result in the expected revival of the vegetation, presumably because of the lack of animal action in aiding reproduction.

It is often felt by stockmen that ungrazed plants are not so healthy and vigorous as lightly grazed plants, and research seems to indicate that properly grazed plants are as productive as, or more productive than, ungrazed (19, 37). Although this may seem an impossibility, there is some argument to support the theory. A grazed plant is like a pruned plant, and every nurseryman or orchardman knows the value of pruning to the woody plant. Upon grazing, the plant will branch and become more bushy, and the forage will be less rank and fibrous. Grasses tend to spread and form a denser sod when grazed, provided that sufficient soil moisture is available. Farmers sometimes graze fall wheat in the belief that they obtain a greater tillering and hence more grain stalks.

In arid regions, it is quite possible that grazing induces better moisture relations since, with the removal of herbage, the transpiring surface is reduced and plants may be able to stand more drought.

The influence of grazing animals in adding fertilizer to the soil is probably not of material value; for the animal, in reality, removes rather than adds fertility. It is true that animals, through digestion of organic material, make the elements more immediately available to plants, but they cannot add any material that would not, through normal decay, ultimately become available.

Graber (13) found that frequent harvesting of plants made them more susceptible to winterkilling and to insect injury. Observations indicate that both insects and rodents prefer overgrazed ranges to those which are

properly used. Grasshoppers in Oklahoma (27) increased enormously in numbers upon overgrazing, though most insects were more numerous under light grazing. Birds generally were rare or absent on overgrazed lands. Small mammals varied greatly; most species were least numerous on severely overgrazed but uneroded land, and cottontail rabbits, deer mice, and pocket mice were most numerous on eroded overgrazed lands. Many workers have recorded that rodents show a preference for overgrazed lands (33). Thus, the changes brought about by grazing can be looked upon as both zoological and botanical; grazing is, then, a biological problem.

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CHAPTER 5

PLANT ECOLOGY IN RELATION TO GRAZING

Plant ecology is *that phase of biology which deals with the mutual relationships existing between organisms and between the organisms and their environment.* Since range plants and range livestock are biological organisms, their interrelationships are ecological in nature. Range management is applied ecology since it consists of manipulating the environment in which both plant and animal live, in such a way as to provide each, as far as practicable, with its most favorable habitat.

The grazing animal is a part of the plant's environment, and the plant a part of the animal's. So long as the two live together, the welfare of each is dependent upon the other. This concept is fundamental in range management. Never can the forage and the livestock be considered separately. Each of these, in turn, must be looked upon as a part of a great and intricatedly related biological complex. The parts of this complex, so-called *habitat factors*, can be classified as climatic, edaphic (pertaining to soil), biotic, and physiographic. Fire also is sometimes included as a separate factor.

Nature tends to balance each member of this complex one with another, sometimes referred to as the *balance of nature*. This principle of ecology assumes that any organism must reach a point of equilibrium between related factors, such as its food supply, its predators, its diseases, and its physical needs, including temperature, moisture, and protecting cover favorable to such life processes as reproduction. This does not imply a static relationship far from it! Nature is dynamic. Constant fluctuation is the rule. Wet cycles or cold cycles induce widespread cycles of disease, population change, reduced food supply, etc. The important point is that such changes are the product of a changed environment. Interrelationship is inevitable. Whenever we change through management any one factor of this complex habitat, we must expect change elsewhere.

Range livestock, although not a natural factor of the habit, become nonetheless a part of nature's great plan. Stockmen must realize that this change, this introduction of a new element into nature's balance, must introduce also widespread changes elsewhere in the habitat. No one knows all these complex interrelationships, but the range manager must

be aware that the relationships exist. Ecology is the foundation of intelligent range management.

Divisions of Ecology. Plant ecology is divided into two phases: *autecology* and *synecology.* Autecology deals with the response of the plant *as an individual* to its environment. It is closely related to plant physiology. Chapter 4 deals in large measure with autecology. The present chapter deals largely with synecology, the response of plants *as a group* to their environment. This is akin to the science of sociology among human beings, how they react as a group. Indeed, synecology is sometimes called *plant sociology.*

Just as the individual plant grows, matures, and reproduces, so also does the plant community develop. The occurrence of a certain plant in a certain place, or the grouping of plants, usually does not come about by chance location of propagules. Rather, it is the direct result of a long series of developments controlled by climate and, to some extent, by soil. Soil, in turn, is a product of vegetation. Without vegetation, we can have no soil. Since soil is so intimately related to vegetation, a thorough knowledge of soil as a habitat factor is essential to a good understanding of range management.

SOIL DEVELOPMENT

Role of Parent Material in Formation of Soil. Soil is a product of the action of climate and vegetation upon rock material. The effect of the rock material upon the end product is variable, but since most rock and mineral mixtures contain all essential elements, general opinion holds that the parent material has no great influence upon the mature soil when compared with the influence of climate. This is especially true if only soil-profile features are considered. However, it is difficult to reason that parent material has no influence, since no amount of weathering and plant action can create mineral elements that were originally absent. Soil-mineral deficiencies may result from deficiency in the original material. There is reason to believe that the parent material may influence the texture of soil since the formation of clay is dependent, to a large extent, upon the nature of the parent material. For example, quartz weathers very slowly, and quartz soils will remain sandy despite age. It may be said that in geologically young soils, parent material is of great importance in determining the nature of the soil, but as weathering continues and as the soil approaches maturity or climax, it becomes increasingly less important and climate increasingly more so, though the influence of parent material is never completely overcome.

Climax Soil. Soil undergoes a series of developments from the original rock and becomes, ultimately, a *climax soil,* which may be defined as a

soil that is in a state of relative stability or balance with weathering and plant action. On a climax soil, erosion is at a minimum; horizonal development has progressed as far as possible under existing climate, and downward movement of soluble materials by leaching is in balance with the upward movement by water and plants. Organic deposition is at a balance with decay. A biological balance is attained among the many minute plants and animals which inhabit the soil. Such a balance comes about only after many years of weathering. The nature of the product is primarily determined by climate but is also influenced by physiographic position, parent material, age, etc.

Jenny (7) has suggested the formula

$$\text{Soil} = \text{function of } cl, o, r, p, t$$

where cl = climate
o = organisms
r = relief or topography and exposure
p = parent material
t = time of soil formation

Since soil is a function or product of these factors, a change in any one will induce a change in soil development.

Since soil and vegetation are so intricately related, it becomes obvious that these five soil-forming factors are the same factors which determine vegetation (8), and the following formula is suggested:

$$V = \text{function of } cl, p, r, o, t$$

where V = any property of vegetation that can be expressed in quantitative terms. Thus, in a sense, vegetation is not determined by soil, soil is not determined by vegetation; vegetation and soil develop concomitantly (8). At any one stage the quantitative aspects of vegetation are determined by soil; and if the soil is defined within areas of uniform climate and relief, then vegetation also is defined.

Following this reasoning, it is obvious that, as the soil develops and approaches climax, so also does the vegetation. With each phase of soil development is found a specific plant development, though the flora differs according to the climate under which it develops. If undisturbed, a climax soil will support a climax vegetation, both of which are in a condition of *approximate stability*, at balance with the climate. A climax vegetation is undisturbed by man or man's activities. It is a *natural* vegetation which has completed its development to a condition of relative balance. It changes or fluctuates; but it is no longer following a *trend* toward a fundamentally different condition. As the climate fluctuates, so do the vegetation and, to a lesser extent, the soil. Nature is ever variable, and

annual or cyclic waves, in the main controlled by weather, are always present. A static condition is never known in nature. Climax vegetation is in a state of dynamic equilibrium (12).

Temperature and, especially, precipitation determine more than any other factors the speed with which soil and vegetation develop toward the climax. Vegetation is more abundant in warm climates having heavy precipitation; and, thus, more organic matter enters the soil. Weathering is greater under heavy precipitation, and leaching, together with organic accumulation, is the major action in soil formation. Because of low precipitation, in most of the West movement toward a climax is slow. Steep topography has not been conducive to stable soils; hence, much of the mountainous West has not yet reached the climax condition. This fact is one of extreme importance to the range ecologist, and he should not be misled into believing that all subclimax conditions are due to retrogression from a once superior condition rather than a normal lack of development. Only careful studies of relict plants, root remnants, protected areas, and historical records will show whether a higher development of soil and vegetation once existed. Such an analysis is not easy, but it is basic.

The succession or development of soils has received remarkably little attention, yet the concept is vitally important, not only to the range manager, but to all agriculturists.

Origin of Soil. In the process of reaching stability, the materials which make up soil may have been moved from one place to another, but most soils originate from rock. This rock is acted upon in many ways by plants and, later, by lower animals. Under the plants, moisture does not evaporate so rapidly; hence the rock is kept wet. The plants form carbon dioxide as a by-product of respiration, and this with the water forms carbonic acid, which eats into the rock surface. The mechanical pressures with which plant roots force their way into rocks are tremendous, amounting to several hundred pounds per square inch. Small plants and animals within the soil play an important role as development continues. Weathering assists in disintegrating rock—wind, sun, rain, and freezing. These mechanically flake off stone and force great cracks to open. Organic matter accumulates, and organic acids accelerate the decay of rock materials. Oxidation and reduction of inorganic and organic compounds cause infinite changes in the chemistry of the soil compounds. Cation and anion exchange among the organic and inorganic colloids is a continuous process; and the complexity of the chemical reactions and the variety of compounds which may result from these actions are great.

Following and accompanying the above transitions is the influence of leaching. Leaching, or eluviation, of the soil removes soluble salts and colloids from the surface layers and carries them to deeper layers. a process which results in the development of distinct horizons.

Lime, which is readily soluble in CO_2-bearing water, tends to be leached from the surface soils. In the West, accumulation of lime in the subsoils is common, and lime layers or *caliche* hardpans often result. Sodium clays, being dispersed, are readily moved downward by water, but when they reach the areas where calcium is concentrated, they are flocculated to form a clay layer. Where rainfall is sufficient to leach calcium from the soil profile entirely and leave it acid, no such layer will form. Where precipitation is very heavy, soils, especially devegetated soils, may be washed to the point of sterility, for there is a general downward movement of small and soluble materials. Since organic matter is produced in abundance on normal forest soils, they are not sterile despite rapid decay and leaching. Because of leaching of soluble salts by acid solution, most soils in high precipitation areas tend to become increasingly acid.

Plants are an important influence in soil formation. For example, pastures on cleared forest soil tend to develop grassland soils, and wood lots planted on grassland soils tend to develop forest soils (4). There are differences in the organic residues of various plant species as well as differences in microclimate under them. Both these factors are important in affecting soil development. Grasses absorb and transport especially large amounts of bases from lower soils to the surface. Generally such soils do not become acid as they develop, and calcium is present in quantity (13). Forests, especially coniferous forests, produce litter lower in bases such as calcium; and soils developing under the forest often become highly acid in reaction. This situation may be reversed under certain climates. Thus, grassland soils may be acid in areas of heavy precipitation, and forest soils may be basic under certain climatic conditions.

Stages of Soil Succession. Soil succession begins with solid rock and passes through a gradual transition to fine rock particles. Organic matter is added gradually at first but later at an increasing rate. As the soil develops, a greater number of species can grow thereon, and more organic acid is liberated, which makes available increasing amounts of inorganic materials. Infinite chemical, physical, and biological activities so completely alter the soil mass that the rock materials lose their identity. This is a definite stage in soil succession and differentiates the young and the old soils.

Concurrent with the above processes is leaching. Speed of development and depth of horizons are determined by quantity of precipitation and depth of penetration. Leaching removes soluble materials, which are largely basic in reaction, from the A horizon, and they are either carried into the ground water or deposited in the B horizon. Also, small clay particles are moved downward and deposited. Another stage of succession is marked by the formation of well-defined clay and lime layers and a sharp differentiation between horizons. The point at which lime is all

leached from the surface soils is a vitally important point in the developmental succession of a soil. If precipitation is high, still further leaching will take place until an acid condition is induced. In areas of high temperature, oxidation is rapid, and organic matter is decomposed readily.

If soil value is measurable in terms of volume of plant production and diversity of organisms which it can support, then it likely reaches a high point at that stage of succession when the reaction is near neutral and organic matter high. Such is the prairie soil. This soil has developed beyond the arid western soils. Undeveloped arid soils are rocky, shallow, low in organic material, and poorly defined as to horizons. Many are high in salt content and alkaline in reaction. The prairie soils are near neutral in reaction, deep, and black with organic matter. Development beyond the prairie soils, accomplished under heavy precipitation, continued leaching, and high temperature, generally results in decrease of organic material, disappearance of lime, and rising acidity. Such a soil frequently is more sterile and produces a lesser volume and variety of vegetation. On very immature soils, the soil is probably more important than climate in restricting plant growth, but as the soil improves with the development, climate becomes more important in determining vegetation. On highly developed, acid, sterile soils, soil may again become the factor limiting species and productivity.

Climate controls soil development and may arrest soil succession at any stage to bring about a climax beyond which development will not continue. Perhaps it should be emphasized that, in soils, the climax does not necessarily represent the most productive condition.

PLANT SUCCESSION

Plant succession is the process whereby one association of species replaces another. Such a succession usually is gradual and involves a series of changes which follow a more or less regular course. The word *succession* comes from succeed. In other words, one type of vegetation succeeds or follows a former type into the area. Succession results from a change in habitat and invasion of new plant species. Remember, plants are always seeking balance with their environment. Change of environment or habitat results in change of the plant cover adapted to the area. Change in habitat (*reaction*) sometimes results from action of plants upon soil and microclimate. Thus the plants themselves may initiate the change which ultimately will result in succession and their own destruction.

Understanding of plant succession is basic to range management. The range manager works with the plant habitat to direct plant succession toward his desired objective. He needs to see and understand successions in early stages as the succession is the measure of the effectiveness of his

management. He must recognize it early if he is to avoid costly loss of time.

Succession may be either natural or induced. *Natural succession* takes place until climax conditions are reached. It results from soil changes in the process of soil succession. Also, both before and after climax is reached, advancement or recession of the process may result from fluctuation in the habitat. For example, extensive decline in vegetation during unusual drought periods is a perfectly natural phenomenon. *Induced succession* results generally from the action of man. Distinguishing between natural and induced succession is important. Induced succession results from man's action, and hence is not a condition imposed by nature. As such, it can be modified by man much more readily than can natural successions. Abnormal vegetation cover may remain for many years, especially in instances where soil erosion follows destruction of the climax plants and induces subclimax soil. Such a condition easily may be confused with a soil-plant complex which has never reached climax, unless careful study is made. The presence of a climax soil definitely will indicate the former existence of a climax plant cover, for the two can never develop separately.

Natural plant succession, on arid lands, moves slowly and the stages are but relative, the end of one and the beginning of a new being ill defined. The trend is toward a more exacting plant group, the individuals tending to become more specific as to requirements.

Large plants have a positive advantage in their ability to shade out competing species of lower stature, but they have an inherent disadvantage in that a large surface area means large transpiration loss. Succession on dry land changes the habitat from the xeric to the more mesic condition; hence, the vegetation changes are from small and drought-resistant species to larger and less drought-resistant species. Other factors influencing plant competition, such as root spread, reproduction capacity, and shade tolerance modify the trend, but generally succession follows a more or less similar pattern.

Succession involves a change in species composition and also a change in plant abundance. As soil develops and its moisture-holding capacity increases, greater plant density results.

Stages of Primary Succession. The term *primary succession* generally is applied to natural plant succession on previously unvegetated areas leading to a climax. *Secondary succession* refers to a succession, usually induced, on land which previously has been occupied by a more highly developed vegetation destroyed by some unusual circumstance, such as fire. Often, soil already is developed beyond presently existing vegetation.

Because of the great variety of habitats upon which succession can begin, there are also a vast number of possible vegetation combinations (11).

Large areas of range land originated from deposits of wind- or water-moved soil. Under such conditions, soil formation and modification was not extensive. Other range lands originated from dry rock surfaces where a typical xeric succession (13), involving thousands of years, was necessary for formation of even a thin layer of soil. Under such conditions, few species are able to survive the aridity of an almost soilless environment. Lichens and xeric mosses which are able to absorb and hold precipitation against desiccation may be the sole occupants until soil depth is sufficient to store water for less specialized plants. These early invaders form carbonic acid from carbon dioxide and water which, together with mechanical forces of the rhizoids, tend to erode away the rock surface. These rock particles, together with organic and inorganic dust particles from the atmosphere, are physically retained by the plant thallus to form shallow layers of what ultimately is to become soil.

Larger and more advanced plants are able to invade as soil and moisture conditions become more favorable through the process of reaction. The soil development thus progresses at an ever-increasing rate. Plant roots penetrate minute cracks with such force as to break rocks. The increase of soil depth and the greater shade resulting from the taller growing plants creates an increasingly mesic habitat. Gradually, longer-lived plants and those of greater stature gain in prominence. A dense forest may be the final product. Evaporation and extremes of temperature are decreased, humidity is increased, and drought periods are shortened.

Early plant succession progresses at a rate controlled by the rate of soil succession, but climate determines the end point of succession, and ultimately arrests the succession at a point which we call climax. This, in arid regions, is a point where available precipitation is effectively used, and invasion of species requiring more favorable moisture relationships will never be possible under present climate because of deficient precipitation. Weathering and plant action previously produced soils that could support a successively higher type of vegetation; now, although there will be variation from year to year, there no longer will be active trend and development toward another type of vegetation requiring more favorable growing conditions.

Effect of Grazing upon the Plant Community. Any of a great number of actions may disturb the climax plant cover and bring about a *retrogressive succession*, or one which leads away from the climax. If this action is temporary, a *progressive succession* leading back to climax follows.

By far the most important of the factors bringing about retrogressive succession in the West is improper grazing The retrogression of a plant cover under grazing does not follow in the reverse order to the succession that gave rise to it, because the retrogression is usually of vegetation and not of soil. Since the climax soil is less easily damaged, it is more permanent than the vegetation, and its retrogression lags far behind. The stages

of grazing retrogression in vegetation, then, are determined, not by climate or soil, but by the newly introduced biotic factor, livestock.

Unfortunately, with continued weakening of the soil-protecting vegetation by grazing, soil deterioration also occurs. Water or wind may move away the developed surface soil to the point that exposed subsoil is incapable of again supporting climax plants. Succession to the climax therefore, must again await development of a new soil mantle. Periods of hundreds, or even thousands, of years may be involved. Especially in dry areas, such as the western range, soil formation is a very slow process. This fact should be kept constantly in the mind of the range manager, for no amount of management will return the range to full productivity if the soil cannot support the desired plants. Soil retrogression caused by erosion and trampling may progress so far that vegetation may be held in a subclimax stage, even though grazing has ceased entirely. Absence of a rapid secondary succession following good management often confuses the range manager, since vegetation cannot respond to improved grazing conditions as he expects.

Retrogression of vegetation under grazing may follow a multitude of courses, dependent upon vegetation and type of grazing.

Grazing during a restricted season may harm only certain species, whereas others may be benefited because of reduced competition. If a short grazing season results in use of a certain species during a critical growth stage, that species may disappear. Another plant, fully as palatable, may thrive or even increase its numbers, because grazing does not occur in its critical period. Balsamroot (*Balsamorhiza*) may disappear from spring range under such conditions because its flower heads are highly preferred by livestock.

Similarly, because of preference differences among kinds of livestock, grasses may increase on a sheep or deer range at the expense of forbs and brush; conversely, on cattle ranges grass may disappear.

Too intensive grazing is marked by a disappearance of the preferred plants or of those physiologically less resistant to grazing. Retrogression, thus, involves plant competition. The removal of climax plants by abuse beyond their endurance, leaves space for other plants. Less preferred or more resistant plants may survive and replace the removed plants. These species are sometimes referred to as *increasers*, because they increase under heavy grazing. Continued grazing will cause an influx of species, often annual, which are not a part of the climax. These are called *invaders*. (See also Range Condition Classification, pages 177–188.)

Stages in Vegetation Regression Induced by Grazing. Some stages of retrogression following improper grazing are easily recognized and are characteristic of most retrogressions. A complete understanding of these is essential to the range manager.

1. *Physiological Disturbance of Climax Plants.* The most preferred climax plants, under stress of heavy grazing, lose vigor, as evidenced by reduction in annual growth; reduction or complete absence of reproduction activity; and, in woody plants, abnormality of growth induced by removal of the growing tip and excess stimulation of lateral buds (Fig. 39)

2. *Composition Changes of the Climax Cover.* Continuance of physiological disturbance of the preferred plants results in their death. Death and disappearance may result from starvation following reduced photosynthesis, competition from other plants less weakened by grazing, natural old age accompanied by a lack of reproduction, or drought made more serious by a weakened root system. Composition change on the range usually is

Fig. 43. Burroweed (*Aplopappus tenuisectus*) a worthless shrub increasing on desert grasslands in the Southwest with overgrazing.

gradual, marked first by a decrease in (*a*) the most preferred plants, and (*b*) the plants physiologically and anatomically most susceptible to grazing damage. Accompanying the decrease in numbers, is a decrease in competition, which results in an increase of less preferred or more resistant individuals (increasers). Animals change their diet, because of increasing shortage of desirable species, to those less preferred. Succession, thus, continues, with better climax plants progressively becoming fewer.

3. *Invasion of New Species.* Following, or simultaneous with, these composition changes comes the invasion of new species, which may or may not have been present in the primary succession but which were not constituents of the climax cover. The first invaders are mobile annuals, but, later, the invasion of herbaceous or woody perennials of low grazing value often takes place (Fig. 43). The annual invaders may be highly preferred by stock for a short season, but they are adapted to thrive despite grazing.

Most invading perennials are not highly preferred by stock, and many are valueless. This, and previous stages, are marked more by decreased quality than by decreased quantity.

4. *Disappearance of Climax Plants.* Climax plants, ultimately, may disappear. They leave first from the most accessible and, hence, most grazed areas, and soon are evident only under the protection of a stout shrub or thorny cactus. Later, even these disappear, often to leave nothing but annual invaders (Fig. 44).

FIG. 44. The relatively bare ground which follows excessively heavy grazing is invaded by undesirable biennials such as gumweed (*Grindelia*) and short-lived annuals such as downy bromegrass (*Bromus tectorum*), as shown here.

5. *Decreased Density of Invaders.* Continued heavy grazing forces stock to consume the invading species which suffer as did the climax species. The most preferred and most susceptible species are removed first, and the less valuable temporarily increase in numbers. As grazing continues, these may bear the brunt of the grazing, and their numbers will decrease. These are not followed by new invaders, but, rather, the land approaches a barren state, with soil regressing rapidly.

Secondary Succession Following Retrogression. The secondary succession following improved grazing conditions usually differs from the initial or primary plant succession since good soil conditions may remain. Frequently, however, soil retrogression follows plant retrogression, because of erosion and trampling. In such cases, secondary succession may be almost

as slow as primary succession, and follow in very similar steps toward the climax.

When soil has not deteriorated along with vegetation, succession of vegetation, upon removal of grazing stress, may be very rapid, especially in areas of high precipitation. It is especially rapid if climax plants remain to seed the area but slower when all climax plants have been removed. The speed, in the latter case, is dependent upon the mobility of the propagules of climax plants, and it may involve many decades. Indeed, some areas appear to be so completely and effectively dominated by exotic invaders that it seems doubtful whether climax plants ever can reoccupy the area under any economic form of use. It is doubtful, for example, that the California annual-grass ranges should be grazed with an objective of returning them to perennial cover. The range manager must assess each such area to determine practical feasibility of his management objective. Invaders may be highly productive and perhaps ideally suited to certain purposes. Annual grasses, for example, may be superior spring lambing range.

Practical management may maintain climax cover but, often, a vegetation cover just under climax proves most practical. It is impossible to obtain the best use of a range without some disturbance, and the rancher cannot always have climax vegetation as his goal. There is error in a too liberal viewpoint, however, and the many tragic results of inadequate attention to maintenance of good forage far outweigh the short-lived profit from excess numbers of stock.

INFLUENCE OF IMPROPER GRAZING UPON PLANT COVER

Improper grazing results in an increasingly less desirable plant cover which often is less dense and shorter-lived. Reduction in yield is important because it increases the work the animal expends in obtaining forage. The actual time and energy used in obtaining feed on overused range is an important factor leading to reduced gains.

Plants that invade with overgrazing are not prominent in the climax cover because they cannot withstand competition. They invade upon the reduction of competition which accompanies decrease in density.

Annual or *ephemeral* plants are especially adapted to disturbed areas or *open communities* of plants. A *closed community* is so fully occupied by plants that new ones cannot readily invade. Here, soil and moisture resources are fully used, and there is no room for additional plants. This does not mean the forage is dense. Dry areas may be fully occupied and still display bare surface soil (Fig. 45) which will be filled underground by roots. Bare ground should not be considered an indicator of unoccupied area or an ecologically open community.

Annual plants may furnish severe competition to perennials for short periods of time, despite the fact that they are generally regarded as poor competitors. They sometimes form dense stands and fully occupy the land during favorable moisture periods. Perennials find such areas difficult to occupy. Seeding perennial grass into an existing stand of annuals is almost sure to result in failure. However, the deeper-rooted native perennials under good management ultimately will compete successfully for the area during seasons unfavorable for the annual. Once established, they form closed communities generally impregnable to annuals (Fig. 46).

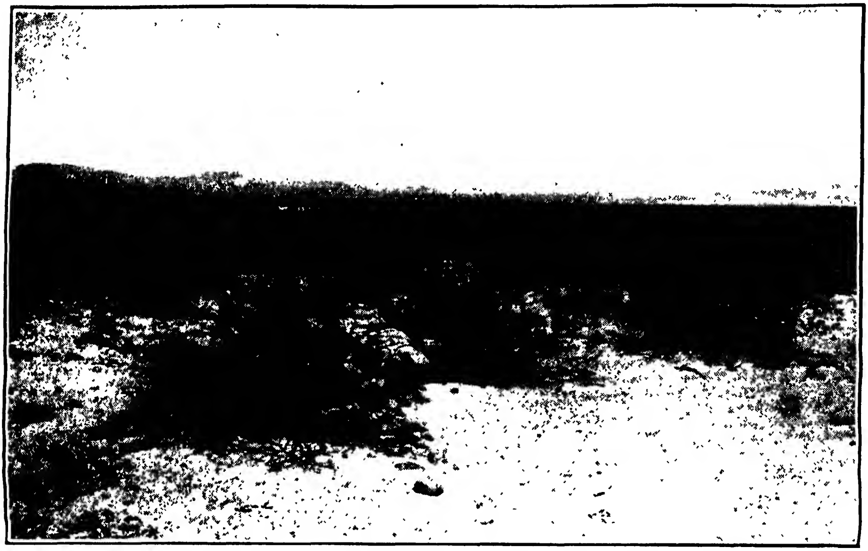

FIG. 45. Arid deserts support sparse stands of shrubs with well-developed root systems. Bare spaces between the plants of creosotebush (*Larrea divaricata*) shown here are occupied by these roots which tend to prevent invasion of other plants.

An understanding of *plant competition* is important to range management. In general, the best-adapted plant can compete best, because it can make most efficient and full use of the resources offered by the environment. Trees compete best because they are tall and can shade out smaller species. But the very size of the tree prevents its growth in dry areas because of its tremendous transpiring area. Usually the largest plants which can thrive under existant soil moisture will dominate. These will be perennial so they can guard their ground throughout the year, instead of just temporarily. They may be slow, but they will be efficient in occupying new areas by seed or by rhizome. The flora which they create generally will be the most productive and densest possible on the area. From a grazing viewpoint, they usually, but not always, are of the highest qual-

ity. Thus, alteration of the climax cover generally involves deterioration in quality of forage as well as quantity.

Value of Invading Species. The preference which an animal displays for a plant is not an accurate index to its value for grazing. Animals can be forced to eat almost any plant, and some of the less-liked species are as nutritious as are the preferred. Animals, sometimes, do as well on so-called low-value plants as on the more preferred. A slight decrease in palatability of the plant cover after excess grazing may, in itself, be no indication of reduced value. Usually, however, invasion of less-preferred

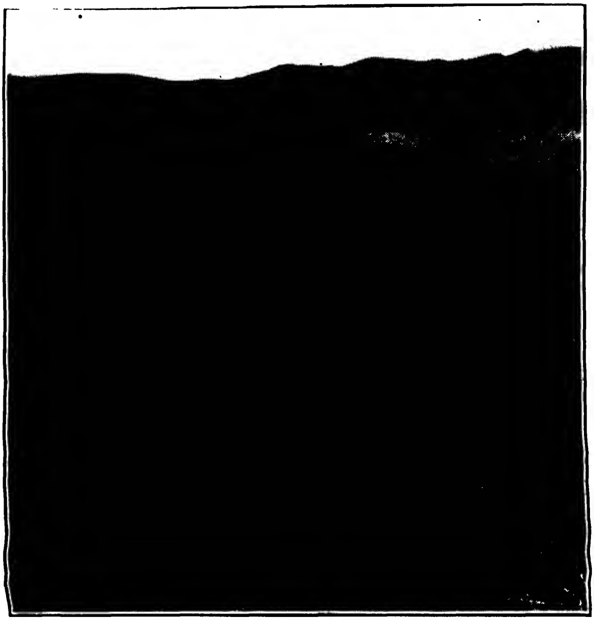

FIG. 46. An experimental planting of crested wheatgrass spaced 12 inches apart is effectively prohibiting invasion of annual bromegrass and other weeds shown to the left and in the foreground despite abundant seed supply and apparently unoccupied soil between the rows. On arid ranges, perennial grass in rows as much as 18 inches apart may form closed communities safe from invasion by annuals.

species is accompanied by marked reduction in grazing capacity, independently of volume yield. This, probably, is attributable to the fact that animals eat less of feed which they do not like, rather than to nutritional difference. Many invaders actually are highly palatable and valuable forage. Notable examples are bur clover (*Medicago hispida*) and alfilaria (*Erodium cicutarium*). Nutritional studies have failed to show consistent differences between climax and invading species except that invading ephemerals are likely to become dry earlier and to deteriorate more upon drying than are long-lived perennials.

Unfortunately, western climates are hazardous for establishment of young plants and, since this process is a frequent necessity for short-lived species, their dependability is greatly reduced. Annual plants depend upon a favorable period each spring during which they can germinate and send their roots to the moist subsoils. Such a period is far from a surety over much of the West, and hence, failures are common. Fluctuation in forage volume from year to year is much greater on ranges high in annual plants.

Annuals are, likewise, more variable in their season of growth. Perennials, having deep roots already established, are less dependent upon current precipitation and more upon temperature, which is less variable, for their start of growth. Annuals are dependent upon precipitation for initiation of growth and may reach their period of productivity at vastly different dates from one year to another.

Annuals are short-lived and are best grazed during their green period, often only six to eight weeks, which may not fit well with the management scheme.

Most poisonous plants are low in palatability, hence increase upon heavy grazing is inevitable. It is believed that losses from many poisonous plants have greatly increased with depletion of the western ranges. Regression following misuse is the greatest single factor contributing to poisoning (see page 235). Gradual invasion of low-quality species and decline of good forage, indeed even serious decrease in total production, may escape notice of the range manager. This decrease in forage ultimately forces animals to eat plants which normally remain untouched.

Many losses attributed to other factors are indirectly a result of forage deficiency. The losses of livestock from increased disease accompanying malnutrition are high. Losses from predators and parasites are known to be large in weakened flocks. Drought and severe winters result in more damage if animals are in poor condition. In some years, losses on overused ranges reach 25 to 35 per cent. Malnutrition causes physiological disturbances, decreased gains, decreased calf and lamb crops, and decreased quantity and quality of wool. Healthy animals and maximum production cannot be expected on sick ranges.

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CHAPTER 6

TECHNICAL METHODS

Technical range management is a relatively new science compared to many other technical fields. In many cases the techniques are not new but were already used in other fields. There are two major groups of methods: extensive, or general; and intensive, or detailed. The former, which hold a very definite place in range management, are used primarily in applied administration; the latter are used mostly in research studies. All these constitute the technical field of range management and are the subject of this and the following chapter.

THE USE FACTOR

The use factor is an index to the grazing use that is made of forage species, based upon a system of range management that will maintain the economically important forage species for an indefinite time. It is expressed as the percentage of the current year's weight production, within reach of stock, that is consumed. In many publications the term *palatability* is used synonomously.

One thing which determines the use factor is how well animals like the particular species. This is referred to as *preference*. Preference is determined by the choice an animal makes if given free access to various plant species. For example, a hungry animal might be forced to eat as much wheat straw as alfalfa hay; but if both were placed before him, he would choose the alfalfa, and therefore its preference rating would be higher.

A use factor of 50 per cent indicates that a plant will have half its total available annual production of vegetation removed by livestock at the end of the grazing season. This implies that livestock management practices have been orderly and that there has been proper utilization of the range. The use occurring on overgrazed ranges is not, correctly, the use factor of a species.

In a way, the use factor is a measure of the relative value of a plant because, if animals will not eat the species, then, of course, it has little value on the range.

The ability of a plant to withstand grazing is not considered either with

reference to its preference rating or to its use factor, except as the physiological abilities of the major species are considered in specifying a proper use for the range as a whole. The use factor, then, is dependent upon the ability of the range as a unit to withstand grazing, and not upon the ability of the particular species in question to withstand grazing. The use factor is not a constant but is dependent upon many modifying conditions.

It will be obvious that the diet of an animal will be a product of (*a*) his forage preference, and (*b*) the available forage. When an animal is placed on previously ungrazed range, he may skim off the most preferred forage, which may make up the majority of his diet. On a fully used range the most preferred plants will have been grazed so closely that they are likely to be an insignificant part of the current diet. Thus, preferred species will constitute increasingly less of the diet and less desirable plants increasingly more of the diet as the range approaches full use. Diet on a previously ungrazed range is an accurate index to forage preference. This diet is not an index to use factor. The use factor is the total utilization of a species after full (correct) use has been made of the range; and it is a product of preference and quantity available.

Composition of the diet, as shown by stomach-content analysis, sometimes is incorrectly used as a measure of animal preferences. Either diet or per cent utilization alone is a poor index to animal preference (Table 23). For example, on a sagebrush winter range in central Utah,

TABLE 23. PER CENT OF AVAILABLE FORAGE, DEGREE OF UTILIZATION, AND COMPOSITION OF THE FORAGING SHEEP'S DIET ON SAGEBRUSH WINTER RANGE IN CENTRAL UTAH

Data from Cook and Stoddart (4)

Species	Per cent of available forage	Per cent utilized	Per cent in diet
Agropyron spicatum	2	20	2
Hilaria jamesii	4	50	12
Oryzopsis hymenoides	3	60	10
Artemisia nova	3	65	11
Artemisia tridentata	66	12	45
Chrysothamnus stenophyllus	17	20	19
Gutierrezia sarothrae	5	3	1

preference rating based upon per cent utilization was as follows: black sage first, Indian ricegrass second, and big sagebrush almost the lowest. However, if the preference ratings are based upon per cent of each species in the diet, big sagebrush was the highest and black sage and Indian ricegrass were comparatively low (4). Preference displayed by any animal

will vary with plant association, type of growth, weather conditions, intensity of grazing, and general activity and whims of the animal.

It has been suggested (4) that, for practical purposes, palatability or preference should be placed in four categories: good, fair, poor, and worthless, rather than trying to attach an exact figure. Such a classification would need to be arrived at by observing relative per cent of utilization under normal range conditions where there are nearly equal quantities of all species being evaluated. However, such appraisals should not lose sight of the fact that many plants of low palatability frequently make up large quantities of the grazing animal's diet when abundant in the floral composition. This does not necessarily occur only when other more palatable species are scarce or are all closely grazed, but it results merely from the greater frequency with which the more abundant species comes before the animal in the normal process of grazing. However, some species are avoided almost entirely. Only occasionally do animals actually seem to seek a preferred species; rather, they merely spend greater time foraging upon, and hence graze closer, the preferred plant upon which they chance to come. It does appear, however, that animals on a range with which they are familiar, deliberately travel to a type or area dominated by plants which they prefer.

When forage plants are evaluated on a given range on the basis of economic importance to grazing animals, both quantity present and per cent of utilization need to be considered. The use factor or palatability does not include the abundance or scarcity of a species on the range and does not properly evaluate the economic importance of a plant, unless considered with floral composition or abundance.

The use factor is an index to usability of forage on the range. If it is determined that, on a given range, wheatgrass yields 100 lb. per acre, this total must be reduced if it is to be expressed in terms of forage, for not all the material thus produced will or should be eaten. On the assumption that the use factor of this plant is 50 per cent, the total production of usable forage, then, is 50 lb. per acre, rather than the 100 lb. actually produced.

Variability in the Use Factor. Because of the many variables that influence the actual use made of a species on a specific range, it is difficult to assign a specific use factor. Yet, it is most important in range management to have in mind an objective in utilization. Correct intensity of use is likely more important than any other item in good range management.

The use factor may vary according to (*a*) associated species, (*b*) kind of stock, (*c*) season, (*d*) year, (*e*) past grazing use, and (*f*) undefined local conditions. It should be evident that most of this variation in the use factor is attributable to a variation in animal preference under different conditions.

a. A given plant species varies in its degree of use by livestock according to the plants with which it is associated, the use varying both with the quality and the quantity of the intermixed species. Sagebrush (*Artemisia tridentata*) will be used heavily when it occurs in small quantities associated with other species; yet, in dense and almost pure stands, only a small percentage will be utilized. Some relatively unpalatable grasses such as saltgrass and tobosa, however, can be used heavily, when they occur in pure stands, by fencing the type and holding animals on the area until the grass is fully grazed. Field observation verifies beyond doubt that animals always prefer a mixed diet. They soon tire of pure stands of any forage.

In extreme cases, the influence of species association upon proper use becomes very obvious. A plant of medium preference growing in association with a highly preferred species in about equal proportion obviously should be grazed lightly to prevent damage of the better-liked species. This same species of medium preference, when growing in association with a species of very low preference, however, could be used heavily without damage to the associated species. In each of these instances, the more preferred of the two associated species would be the basis for determining correct use, the less preferred species being used only so much as comes about incidentally to the correct use of the more desirable plant.

b. Use factors vary according to kind of stock. Despite the fact that sheep and goats can be and are raised on grass range, they do not, on mixed vegetation, use so large a proportion of grasses as do cattle and horses. Horses are the most selective of the domestic grazing animals, a large proportion of their diet being grass. Sheep are probably least selective; for, although they eat a larger proportion of forbs than do other classes, they also consume grasses and shrubs with about equal avidity. The goat is famed for his consumption of browse, a feat at which he is undeniably adept.

Wild animals likewise show some tendency toward variation in preference; thus, deer eat more shrubs than do elk, and elk eat more grass than do the deer.

c. The season during which they are grazed profoundly influences the use factor of most plants. Some plants are highly preferred in early season and but slightly in late season, especially after maturity. Most annuals fall in this class. Other plants are more preferred in late season, as the red elderberry (*Sambucus microbotrys*) which is grazed during late summer only. Some plants, such as balsamroot and Russian thistle, are preferred early; then become dry and too harsh for stock consumption; but, when softened by winter snows, again are consumed in large quantities. In Arizona (20) many native species were placed before a group of deer twice daily, and the use of each species was determined. The animal's appetite was the only factor controlling the amount consumed. Individual animals

showed individual preferences, *but there were also definite group reactions.* Emory oak (Fig. 47) showed a variation in preference from 5 up to almost 100 per cent and a yearlong average use of 55 per cent. A rapid increase to the high value occurred in the spring when new growth was made. Juniper displayed a cyclic variation, each 10 days or 2 weeks, from a preference of 10 to 20 per cent up to a preference of 70 to 80 per cent. An animal might make an entire meal of the species and then ignore it entirely for a period of 10 to 14 days, whereupon another meal would be consumed.

d. The same species may vary somewhat in use factor in the same region as a result of climatical variation. In good years, when moisture is abundant, rank growth tends to decrease the attractiveness of the plant

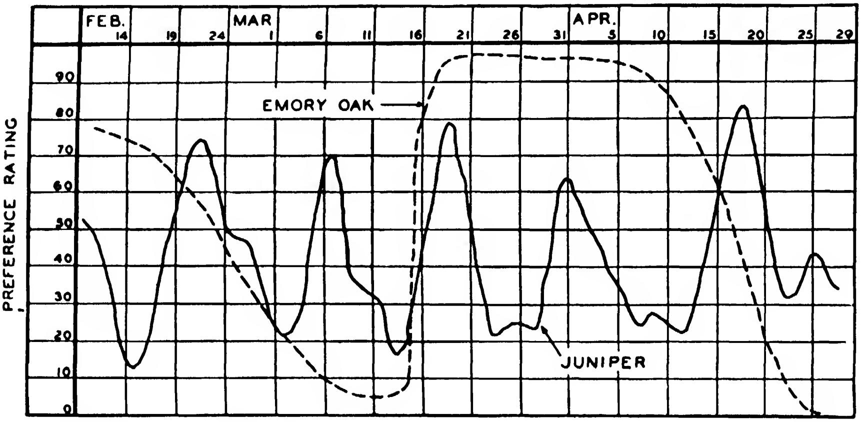

FIG. 47. Preference ratings of emory oak (*Quercus emoryi*) and juniper (*Juniperus pachyphloea*) obtained from artificial feeding of whitetail deer in Arizona during early spring. [*Data from Nichol* (20).]

to grazing animals. An example is Russian thistle, which is consumed in large quantities when it remains small and, hence, does not develop abundant prickles. During extreme drought, plants that are fleshy are more attractive because of their high moisture content. Other plants are improved by excess precipitation. Short plants may gain sufficient height to become valuable forage, whereas in dry years they are too small for animals to consume more than a small percentage of their foliage. Filaree (*Erodium*) is an example.

e. Past grazing use influences animal preferences. Animals tend to return to a previously grazed plant because its regrowth is more tender and leafy, dry stems and leaves being absent. Such repeated grazing results in *spot overgrazing* where the same patches are grazed repeatedly and others are unused. Individual plants, so-called *wolf plants*, may remain ungrazed year after year (Figs. 48 and 49).

FIG. 48. Tall-grass prairie in north Texas showing overgrazed spot in foreground dominated by buffalo grass, needlegrass, and threeawn grass with mesquite invading. To the rear is climax bluestem prairie. Such spot grazing results from repeated use in one area and little or no use of stemmy previously ungrazed plants.

FIG. 49. Seeded range, tall wheatgrass to left and crested wheatgrass to right. Note unused plants (wolf plants) of each species where companion plants of the same species are repeatedly grazed and regrazed. The same plants are untouched year after year.

f. Some plants vary in use factor within the species for no apparent reason, sometimes despite the fact that the individuals grow in close proximity. Possibly local varietal expressions of a species differ in attractiveness to animals. Deer have been observed to show this marked preference for individual plants in the case of juniper. Often one tree will have all the available foliage removed, while a neighboring one will be almost

FIG. 50. These two branches, both *Juniperus utahensis* were placed before hungry, penned deer. One was untouched, the other fully consumed. The ungrazed branch was from a tree observed to be avoided on the range whereas the grazed branch was from the top of a tree hedged by deer as high as they could reach.

untouched. Sheep have been noted to graze closely one sagebrush and to ignore completely another growing alongside. Possibly the salts or minerals taken up by a plant from certain soils increase or decrease its use by their influence upon taste. For example, it has been suggested that phosphorus-fertilized plants develop a high sugar content and that sugar content is the most reliable index to palatability of the forage (24). Also, the variation in essential (volatile) oils in such plants may determine their palatability. For example, branches from grazed and ungrazed

juniper trees were cut and offered to deer in pens. The deer completely consumed branches from preferred trees (Fig. 50) but ignored branches from ungrazed trees of the same species (26). Samples of grazed and ungrazed individuals of red juniper (*Juniperus scopulorum*) and Utah juniper (*Juniperus utahensis*) were analyzed for volatile-oil content. A small but significant difference was found, red juniper averaging 1.84 and 2.27 per cent oil in the grazed and ungrazed trees, respectively, and Utah juniper averaging 2.13 and 2.60 per cent.

Just as individuals of a species vary locally, so do they vary from region to region. *Artemisia frigida* is regarded as an indicator of overgrazing in the northern plains, as fair forage in the central plains, but as good forage in the southwest. Many cases are known where animals shipped from one region to another at first refuse to eat plants that are highly attractive to local animals.

Value of the Use Factor. Aside from the variability of the use factor assigned to plants, there are other reasons why the assigned value may not always be an accurate index to the grazing value of a plant. Since the use factor indicates only the percentage of the total accessible current growth of plant material that is consumed, it does not give any indication of the actual amount of vegetation consumed or of the quality of the material in terms of food value. Thus, it is possible for a plant to have a high rating on the basis of the percentage eaten and yet be unimportant in the total diet and of inferior nutritive value.

The lack of agreement between the use factor and forage production has long been recognized. Standing (27) suggested correcting this inadequacy by multiplying the use factor by a volume rating obtained by placing each plant in a class according to its relative weight compared with an average plant, which received a rating of 1. The resultant value was called *volume palatability*. Though this is a sound procedure, its adoption depends upon the determination of volume production for each important range species and for the different sites on which it may be found.

The use factor likewise gives no indication of the nutritive value of the plant, a fact which restricts its use as a value index. There is no reason to believe that a plant selected by livestock is any more nutritious than another not selected. Recent studies have shown great differences in chemical content and digestibility of range plants, but the data are difficult to interpret in the practical evaluation of each plant as a constituent of the range flora.

METHODS OF ESTIMATING UTILIZATION

Range lands should be inspected frequently to determine current utilization of the forage. The use factor is the estimate of correct use or

desired use. Relating current use to desired use gives a direct index to how much forage remains to be used.

Utilization of a range means *the degree to which animals have consumed the usable forage production expressed in percentage.* This production should be based upon animal-months consumed compared to animal-months available *when the range is correctly used.*

When dealing with an individual plant, however, utilization has a different usage and is defined as *the degree to which animals have consumed the total current herbage production expressed in percentage.* The percentage is based upon weight and is a simple measurement of what part has been consumed *without regard to what is correct* utilization. These two usages are confusing and will require clarification whenever the term is used. It is suggested that *range use* might be a better term for the first meaning and *percentage utilization* better for the second meaning.

Range use involves a number of factors which influence proper grazing such as soil erosion, trampling, vigor of important forage species, and also percentage utilization of current year's growth of primary forage species.

The first attempt at estimating range use was merely an ocular judgment. The old-time stockman judged how near the feed was to being fully used. His judgment was one based upon experience and was often a very accurate one. Among early forest rangers the feeling was that 15 to 20 per cent of the forage must remain if the range was to be perpetuated. The rangers, often old stockmen themselves, called full use as they had known it as stockmen 80 to 85 per cent utilization of the better plants. Estimation came to be based entirely upon height. A plant normally 10 inches high and now grazed to a 5-inch average height was 50 per cent utilized and could be utilized until it averaged only 2 inches in height (80 per cent used) without damage.

The concept of percentage height grazed later was modified to the theory that, rather than leaving 20 per cent of the height, one should leave 20 per cent of the seedstalks for purposes of propagation. Studies (8) on *Agropyron smithii* indicated that this utilization really removes about 52 per cent of the weight of this species and is about correct usage of the plant. Studies on *Bouteloua gracilis* (7) showed that it could maintain itself when about 25 per cent of the flower stalks remained, a utilization of only 40 per cent of the weight.

Lommasson and Jensen (18) suggested a method of correlating weight utilization with height utilization in range grasses. The method consists of weighing each inch of the plant and then constructing a table to convert inches of stubble remaining into percentage of height removed. Their goal was a scale to convert height of stubble for any species into percentage of volume utilized.

Crafts (6) improved this method by the initiation of a height-volume calculation chart as shown in Fig. 51. Percentage height grazed can be converted directly into percentage volume by means of these charts, but a specific chart must be constructed for each species. By use of a ruler. the average height of the tallest flower stalks on ungrazed plants is calculated. Average stubble height on grazed plants is also calculated. By use of the

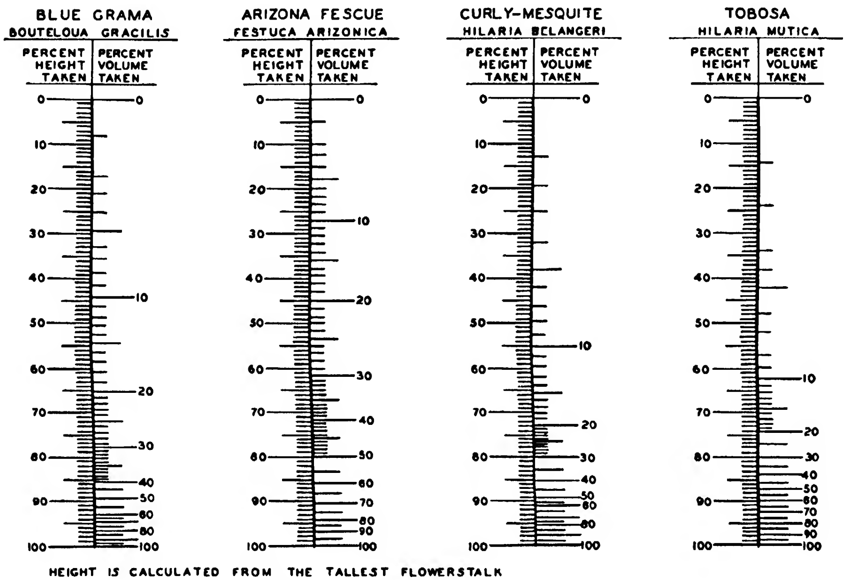

FIG. 51. Height-volume calculation charts for four Southwestern grasses showing the relationship between height utilized and volume utilized. [*Data from Crafts* (6).]

chart, these two measurements are converted into per cent volume removed from grazed plants. Then,

$$\text{Weighted average percentage utilization} = \frac{\Sigma\ (\text{per cent of volume removed from grazed plants})}{\text{total number of plants observed}}$$

Weight Determinations of Utilization. Beruldsen and Morgan (1) in Australia suggested a precise method of determining utilization in which they used two transects of randomized plants, one of which was harvested after grazing and the other without grazing. The difference in yield was assumed to be attributable to grazing, and the percentage utilization was calculated from the difference between the two transects. The fact that the method necessitates either a check area fenced against grazing or a mature vegetation when grazing begins so that an ungrazed sample may be taken before animals are put on the range practically eliminates it from

consideration in ordinary range-management work, except experimental studies. Further, the heterogeneity of most western ranges would necessitate, for any great degree of accuracy, a prohibitive number of plots in each transect to be compared.

Cassady (3) suggested a modification of this method for determining *range utilization* by sheep. His system, called the before-and-after method, involves clipping and weighing green a given number of plant *units*, which, depending on the species, may be a whole plant, a twig, or even a single leaf. Usually, 10 to 20 of these units compose an *observation*. Before grazing, 10 to 20 observations are made of the range yield. After grazing, 15 to 30 observations are made. Utilization is determined from the difference in weight between the "before" and the "after" samples. The method is adapted to sheep range; for there the two collections can be made within one week, and hence no appreciable growth takes place during the test. It has been used on winter ranges, when no growth is taking place, with longer intervals between the before and the after samples. Or, if a comparable protected range is available, before and after samples taken on this area will show what growth has occurred without grazing, which can in turn be used as a correction factor on the grazed range.

Pechanec and Pickford (22) have suggested a method of determining utilization that they call the *ocular estimate by plot*. This method involves the use of small randomized plots, which are studied by trained observers, the utilization being estimated in terms of percentage of total weight consumed. The plants may be considered individually and averaged, to obtain an over-all utilization (ocular estimate by average of plants), or the utilization of the plot as a unit may be estimated. Intensive training is necessary in order to obtain uniformity and accuracy by this method. To develop the efficiency of fieldmen, study plots are artificially "utilized" by clipping, and the herbage removed is weighed. The men then estimate the utilization and are checked by clipping the remaining forage and calculating the actual utilization.

The rapidity of this method enables observers to determine utilization over a much greater area than does a more exact method. Its authors point out that this fact more than offsets the inaccuracy that is inherent in any estimation method.

Percentage of plants which have been grazed also has been used since 1935 as a method of determining utilization of the range as a whole (28). A conversion chart is constructed to correlate per cent of plants grazed with per cent range utilization. Grazed and ungrazed plants are counted on sample plots or at regular intervals along a paced transect, and percentage is calculated. This percentage is converted directly from table or chart into per cent utilization. Studies on forage utilization on Montana

plains (14) found this method to be the most practical and sensitive single criterion for judging relative utilization of ranges.

On desert ranges of Arizona about 50 per cent utilization is considered correct for desert grasses. This point was reached when about 64 per cent of the plants were grazed (25). In this study and the Montana study (14) a constant straight-line relationship was found between numbers of plants grazed and range utilization; however, similar studies on Idaho fescue in Wyoming showed a curvilinear relationship (15) which suggests the construction of a special curve for each species and each range area. In this study, 50 per cent utilization of the fescue was not reached until approximately 80 per cent of the plants had been grazed upon. Suggested numbers to result in proper use in Montana are shown in Table 24.

TABLE 24. GUIDE TO PROPER UTILIZATION OF NORTHERN GREAT PLAINS RANGES IN SUMMER SHOWING NUMBER OF THE PLANTS TO BE GRAZED, IN PER CENT

Data from Holscher and Woolfolk (14)

Species	Upland subtype	Hills subtype	Bottom subtype
Western wheatgrass	55	55	75
Blue grama	40	45	65
Needlegrass	55	60	
Buffalo grass	55	50	75

Ocular Appraisal. Deming (10) initiated a *primary-forage-plant* method for classifying use of the range. This is a method of range inspection, usually used at the end of the grazing season, in which percentage utilization of the primary forage plants is observed, but the end product is based upon correct use of the entire range. In addition to percentage utilization, other factors which influence proper range use are observed and considered to enable classification of each area into one of a number of degrees of use. These observations are made at various points over the range, and the class number is placed on a map. This is then used as an index to uniformity of grazing, showing points where corrective management methods are necessary.

In assigning the range area into a specific class, attention is given to plant abundance and vigor, soil-erosion conditions, topography, watering facilities, season of use, rodent activity, fires, and any other factors that might influence grazing use. Considering all these factors, the investigator decides into which of the following comparative use classes to place the area.

1. *Unused.* No livestock use.
2. *Slight.* Practically undisturbed.

3. *Light.* Only best plants grazed.
4. *Moderate.* Most of the range covered. Little or no use of poor plants.
5. *Proper.* Entirely covered. Primary forage plants correctly grazed.
6. *Close.* Completely covered, with some repetition of grazing. Some use of low-value plants.
7. *Severe.* Hedged appearance and trampling damage. Primary forage plants almost completely used. Low-value plants carrying grazing load.
8. *Extreme.* Range appears stripped of vegetation. Primary forage plants definitely injured. Low-value plants closely grazed.
9. *Destructive.* Much death loss of primary species. Only remnants of good plants survive. Range in a critical condition.

Field men are surprisingly consistent in this classification after a brief training period. This method differs from others in that it eliminates the obviously difficult assignment of a specific percentage of utilization. If management is based upon the ecological principles considered in range-condition and range-trend analyses, it is not necessary for the rancher or land administrator to make precise determination of percentage utilization for individual forage species. General observations appraising utilization and vigor of plants are sufficient basis for adjusting for range improvement. However, accurate measurement of percentage of forage removal by grazing is important to the research worker (4).

An average or over-all use of the range can be determined by computing the use-class average. A range averaging class 5 would be considered correctly stocked; however, areas of stock concentration might exist which cause local problems. Improved distribution would then be indicated.

It should be emphasized that, of the methods discussed here, only the latter gives its answer directly in terms of correctness of range use. The other methods all are aimed at determining percentage utilization of a single species or a group of species presumed to be the most important forage species. The resulting percentage tells nothing as to whether the range is underused, overused, or correctly used. Since for virtually no species do we know what percentage utilization is correct (i.e., what the plant can endure), the value of these percentages is limited to general interpretation or to comparisons of one range with another, or of one year with another. Utilization determination is not an exact science either in method or interpretation.

Indicator Species in Utilization Estimation. Unless he resorts to a few indicator plants, the range owner or administrator will be confronted by a maze of plants, each species being utilized to a different degree, depending upon its availability and upon animal preferences. It is very difficult for even the experienced man to arrive at a correct estimate of the percentage utilization that has been made, especially on ranges of heterogeneous vegetation. For this reason, it is usually the practice of range examiners not to include all the forage plants in the area in the calculation of

utilization but, rather, to select a few important plants. These plants are known as utilization *indicator species* or *key species*, and they should be the most important forage species on the range. Since they usually furnish the bulk of the forage, it is obvious that when they are used to capacity, the range in entirety must be considered as correctly used. On most ranges, correct grazing for the two to four most important forage plants on a range means correct grazing for the entire range.

Occasionally, a highly preferred species that occurs in only small quantities will be sacrificed (i.e., allowed to be overused), in order to obtain fuller use of the more abundant species. These so-called "ice-cream" or "cake" plants cannot be used as utilization-indicator plants, despite their high preference value, if, because of their scarcity, they are not important forage species.

The ecological status of a plant must be known before an accurate decision can be made concerning the advisability of sacrificing it. A climax plant or former dominant species that, because it is highly preferred by livestock, is rare on an overused range may still remain the best forage plant for the area and, in such a case, definitely should not be sacrificed in order to make better use of less desirable plants. It may be desirable to take extreme measures in reducing grazing in order to bring the range back to its former cover. Temporary stock reductions can almost always be justified if they lead, ultimately, to an increased range capacity. There are instances, however, in which the climax plants are not the most desirable or in which mere stock reduction cannot restore the climax plants within an economically feasible time. In such cases, the remnant climax plants cannot be justified as key species. The progressive range ecologist will always manage a range to obtain the greatest forage yield over a long-time period. Only a sound ecological analysis will determine whether the greatest yield can be obtained by protecting a certain preferred species or by sacrificing it.

Forsling and Storm (11) working on southern Utah browse range found that despite the fact that Gambel oak (*Quercus gambelii*) made up 30 per cent of the cover—far more than any other species—it should not be fully grazed. Continued heavy use of the oak would result in permanent removal of all the more desirable shrubs as well as the grasses. Further, cattle made unsatisfactory gains when the oak brush was used heavily, they lost weight during the latter part of the grazing season, and calf crops declined. Hence, the authors concluded that

> . . . the best summer use that may be made of browse range is to graze it only to the degree that will not injure the more palatable browse and the grasses and weeds of approximately equal palatability, even though this will entail but light use of the less palatable species.

On this range only 2 per cent of the cover was made up of highly preferred grasses. The use of these to only a tolerable degree would result in unreasonably small usage of the much more abundant shrubs; therefore, proper use of this range would involve grazing the better shrubs to capacity, even though some of the highly preferred grasses were killed.

Indicator Areas in Utilization Estimation. Analogous to the indicator-plant theory of determining utilization is the *indicator area*, or *key area*, theory. Just as one may select a single species or a specific group of species as a key to correct use, so may he select a representative area within which to study utilization. The principle behind this theory is that no western mountain range and few level ranges can be uniformly utilized. Heavy use is inevitable around water holes, salt grounds, driveways, level valley floors, and more accessible ridge tops. Likewise, lighter use or possibly even nonuse prevails at great distances from water and salt and on very steep hillsides. These inequalities are emphasized when the range is grazed by free-roaming cattle, but even herded sheep graze the average western range unevenly.

Because of this lack of uniformity in grazing, certain areas may be *sacrifice areas* and be overused, just as the rare and highly preferred species may be overused. Other areas may be underused, for their proper use would cause serious overuse and range damage on more accessible areas. The intermediate areas, then, become the indicator areas because they are to be properly used.

Proper determination of the indicator area is extremely important in range management. One must be liberal, or the grazing will be unreasonably light. The beginner in technical range management almost always had difficulty in resigning himself to sacrificing certain areas in order to get an economically full use of grazing land. But one must be conservative, or excess use may be the cause of damaging erosion and permanent decreases in forage yield. Certainly the rule of thumb of the conservationist should be, "Keep the sacrifice area at the practicable minimum." The first obligation of a public-grazing administrator is to protect the resources, and this should also be the goal of a private landowner if he is to protect his land investment and maintain a stable business.

The Key-plant and Key-area Principles Applied. In order to obtain a clearer concept of the indicator-plant and indicator-area principles, let us assume a hypothetical area upon which are three plants, wheatgrass (*Agropyron*), sweet anise (*Osmorhiza*), and niggerhead (*Rudbeckia*). Further, let us assume that the range includes a water hole, an adjacent level bench, and a distant steep hillside. After the range had been fully utilized, we might expect the following percentage use (assuming 60 per cent to be the correct use to maintain the plant):

Plant	Around water hole, per cent	Adjacent bench, per cent	Distant hill-side, per cent
Agropyron	100	60	30
Osmorhiza	100	90	60
Rudbeckia	60	10	0

Assume the adjacent bench to be the key area and the *Agropyron* the key plant. Despite the fact that there are utilizations from zero to 100 per cent, confusing when looked at as a group, all that the observer need consider is the 60 per cent use of *Agropyron* on the benchland. When this plant on this area is properly used, the range is properly used. Under continued use, one would expect that *Agropyron* and *Osmorhiza* would disappear from the area around the water hole, *Osmorhiza* would disappear on the benchland, and all three would survive on the hillside. This hillside could not be fully used if the *Agropyron* on the benchland is to be maintained. Underuse of forage on the hillside should, however, give the maximum forage yield over a long-time period and the minimum of damage to plant cover consistent with a reasonable use. Full utilization of steep slopes should not be expected, and the forage growing on such slopes should be discounted or, on extreme slopes, disregarded when carrying capacity is estimated.

Safe or Proper Forage Use. One of the questions ever present before the range manager and stockman is, "How much can the range be grazed without permanent damage to the good forage plants?" It is very important that this desirable use be known in order that a minimum of forage will be wasted and yet no damage will be done.

The objectives of proper use are clear; preservation of the range values, protection to the soil, and production of the maximum meat consonant with these objectives. The latter cannot be achieved merely by observing animal condition, for good animals may be produced under a condition in which the range is deteriorating. Proper use may not result in climax vegetation. Soil protection, rather than vegetation, may be the criterion. Careful observation of the range as a whole is needed.

Proper use is the utilization of the range forage that is attained when all the land services are given due consideration. The interrelated values of soil, grazing, watershed, timber, recreation, wildlife, and other land services all enter into the determination of proper use. Proper use implies more than resistance to grazing, which is the degree of use a plant can stand year in and year out and still maintain its vigor and forage productivity (9).

How much grazing individual plants can withstand is not known, but certainly there are great differences among species in their grazing

tolerance. Percentage utilized does not give an exact picture of the stress to which the plant is subjected. Among the factors affecting plant response to a given grazing use are:

1. *Current growing conditions.* In drought years plants can stand less use than during favorable years.

2. *Habitat or environment.* On fertile, moist soils regrowth is abundant and herbage is soon replaced. On dry, eroded hillsides, plants are less able to withstand grazing shock.

3. *Season of grazing.* During seasons of depleted food reserves, plants can be injured by grazing intensity that would not injure them during late fall or other less vulnerable seasons.

4. *Duration of grazing.* What appears to be full use at the end of a summer grazing season may result from continued grazing throughout the spring and summer; from heavy spring use followed by rest and regrowth, followed by heavy regrazing; from complete rest during spring and full use just prior to the close of the summer grazing season; or from innumerable other conditions. None of these factors is considered in the usual expression of utilization. Further research is necessary before conclusive proper-use standards are available.

TABLE 25. PRODUCTION AND UTILIZATION OF THE PARTS OF PLANTS FOR SOME OF THE MORE IMPORTANT SPECIES ON SUMMER SHEEP RANGES OF NORTHERN UTAH*

Data from Cook and Stoddart (1)

Species	Per cent of total production			Per cent of utilization			
	Stems	Leaves	Heads	Stems	Leaves	Heads	Total
Agropyron subsecundum	63	19	18	20	39	25	25
Elymus glaucus	75	19	6	6	20	20	9
Average grass	69	19	12	13	29	22	17
Agastache urticifolia	57	33	10	6	60	36	26
Senecio serra	55	42	3	1	70	54	31
Valeriana occidentalis	80	17	3	10	80	2	22
Average forbs	61	31	5	6	70	31	26
Amelanchier alnifolia	20	80	..	26	62	..	55
Symphoricarpos vaccinioides	24	76	..	7	29	..	24
Average browse	22	78	..	16	45	..	39

* Data based upon current year's growth only.

Utilization Affected by Preference for Certain Plant Parts. Preference for certain portions of a plant over others is apparent in livestock, especially sheep. This becomes important in measuring physiological responses of plants and in interpreting correct grazing use. Studies on

northern Utah summer ranges showed that sheep always preferred leaves over stems. Relative production and degree of utilization of these plant parts for selected forage species are shown in Table 25.

Utilization of leaves of grasses and forbs averaged 29 and 70 per cent, respectively, but utilization of the entire plant was only 17 per cent for grasses and 26 for forbs. In some species, only about 25 per cent of the entire plant was utilized when 70 to 80 per cent of the foliage was removed (4). Since the photosynthetic tissue in most forage plants is almost entirely in the leaves, basing degree of utilization on the per cent removal of the leaves might better indicate the severity of grazing use, in those cases where leaves primarily constitute the forage supply. Since, however, this is true for only some plants, using leaves alone as a basis for calculating utilization might only result in confusion. The level at which we set proper utilization numerically is unimportant, provided that we understand that light utilization may mean virtual defoliation in some instances.

Not only do we now have little accurate information on what is proper or safe use of a range, but also we lack a readily usable measure of such use. Performance, as based upon production of livestock over a period of time, is fruitful. It is likely, however, that damage may be done to a range before misuse is reflected in livestock condition. Animals in good flesh may be produced from the range after utilization has passed the safe point; just as soon as feed becomes scarce, however, animal weights will drop. Accurate weight records might reveal this; but since they are seldom available, this phenomenon may pass unnoticed or be ascribed to leaching of the forage. Over a period of years, range misuse will be reflected in decreased production of forage; and then, too late to avoid injury to the range, a sharp decline in animal production will result.

DETAILED STUDY OF VEGETATION

Because of the difficulty in recognizing gradual changes in vegetation over several years, it is necessary to keep careful records on small plots. On federal lands, where personnel changes frequently, it is especially desirable to have records of the range plants, for otherwise it would be difficult for the new range manager to determine whether a species indicating poor grazing practices is coming in or going out. The technical man cannot rely upon casual observation and memory to inform him as to long-time changes in range vegetation but must depend upon detailed and permanent records. Careful study of minor decreases in valuable forage plants, invasion of weedy species, increase of poisonous species, and similar changes will reveal improper management early and thus forestall the need for improvement of a seriously depleted range.

Small plots are used also for appraising the quantity of forage as an aid in grazing-capacity estimates.

Location of Plots. The purpose of small study plots on range vegetation is to sample a portion of a large range, on the assumption that the small areas are typical of the whole. Location of plots in such a manner as to indicate accurately conditions on the range as a whole is fundamental.

Plot location may be determined (*a*) by selection of each spot to be studied or (*b*) by some chance arrangement.

Selection of the plot is used when studying a specific character of the range. For example, to determine whether spots of tarweed are expanding or disappearing, plots would be selected in which these spots occurred. Selected plots are used quite generally to detect changes in the vegetation cover from year to year. Careful interpretation should be made of data gathered from these plots, since they do not adequately sample the range as a whole.

Chance arrangement may be determined by mechanical means whereby plots are located in some regular pattern, by strict randomization wherein all the possible plots of the size contemplated form a pool from which the desired number may be selected by chance, or by a modified random procedure in which plots are located along lines. The location of lines as well as the location of plots along each of these lines is determined by random selection. Ranges of variable topography and vegetation require very large numbers of chance-located plots to be representative of the entire land area to be studied.

Random location is accomplished by determining the number of plots of the size to be used that can be located upon the area to be sampled. Each of these plots is assigned a number. Then, by placing a number of papers upon which these numbers appear into a container and withdrawing the number desired or by using tables of random numbers, the areas to be sampled may be determined free of bias.

Although for practical studies the mechanical location of plots may be entirely satisfactory, the procedure is criticized from the standpoint of statistics, for in so proceeding not all the plots have equal chance to be included in the sample group. However, strict randomization greatly increases the work of sampling, owing to the fact that there is no regularity in the location of the plots. Each plot must be located by an independent set of measurements.

These factors have led to restricted plans of randomization, designed to achieve some of the regularity that attaches to mechanical schemes, while giving free rein to chance, so that appropriate statistical analyses may be applied. This can be accomplished by locating plots along transect lines. The location of these lines is determined by numbering all the possible rows which can be inserted in the area to be examined. These

are numbered, and the lines to be used are determined by reference to a list of random numbers. A second set of numbers is used to locate plots along these lines. Thus some regularity is introduced to eliminate labori ous plot location.

Size and Number of Plots. The size and number of plots will depend primarily upon the kind of vegetation studied. Larger plots require fewer numbers, although, generally, a more effective sampling can be obtained per unit of area studied by the use of numerous small plots rather than fewer and larger plots. Desirable plot size varies greatly with the objective of the study and the study method used. Generally, highly variable vegetation, soil, and topography require larger plot numbers than do more uniform conditions. Smaller and denser plants, of course, require smaller plots than do larger and more open-growing plants.

Ecologists studying small plants like grasses have commonly used a plot 1 m. square. The milacre plot (6.6 ft. square) is convenient to use when the data are desired in terms of yield per acre. Use of a wire hoop with an area of 9.6 sq. ft. (diameter, 42 inches) has been suggested also because, on such a plot, grams of forage produced when multiplied by 10 is equivalent to herbage yield in pounds per acre (12).

Permanent versus Temporary Plots. In general, permanent plots are used for studies involving changes in plant cover, whereas temporary plots are used to measure existing conditions without regard to future change. Temporary plots differ from permanent only in that they are not marked, whereas permanent plots are marked by wood or steel stakes, generally in the center of circular plots and in the northwest and southeast corners of rectangular plots. Line transects are marked by a stake at each end of the line. Such stakes must be located with reference to some permanent and easily located point. Lacking natural features, a rock monument can be constructed as a marker.

Permanent plots have little advantage over temporary plots where the vegetation is annual, for the same individuals will not occur another year. Likewise, plots that are clipped and harvested generally should be temporary, for such plant removal makes the plot atypical.

Plot Shape. Sample plots may be long, square, or round. An elongated plot is called a *transect* and may be either a belt transect or a line transect, depending upon whether it has width. Both square and round plots are referred to as *quadrats*, although technically the word can be applied only to square plots. Transects and quadrats serve the same purpose, except that the transect is ideally suited to sample across known belts of vegetation, soil, moisture, or productivity. It is generally believed that the added length gives no advantage per unit area studied, except when it is at right angles to such belts; hence, if nothing is known as to belts, there is little reason to choose a belt transect instead of a square or

circular plot. The transect is valuable in studying the invasion of plants; for example, the invasion of native range plants into abandoned cropland or the invasion of shrubs into grassland with overgrazing. In the line transect the species and position of plants touching a string, wire, or steel tape are recorded or mapped.

It is possible to calculate herbage density and floristic composition by use of the line transect. This is accomplished by linear measurement of the intercept of plants on randomly located lines, which may be looked upon as vertical planes. To facilitate measurement of tall-growing species such as shrubs, a small cable may be fastened to pins driven into the ground and elevated to any desired height (2).

A modification of the transect method, called the "loop method," is widely used by the U.S. Forest Service as a part of the three-step method of vegetation analysis (21). A wire loop ¾ inch in diameter attached to a long shank is placed on the ground at 1-ft. intervals along a 100-ft. steel tape. A record is kept of whatever plant species is encountered within the loop. If no growing plant occurs within a loop, vegetation litter, bare soil, or rock is recorded. Vegetation density (approximate) and composition can be calculated from these data.

A round plot has an advantage over a square plot in that it can be located by use of one stake only. This is best done by constructing the frame as a stiff wire hoop divided into four or more parts by radial wires leading to a small center hoop which just fits over the stake used to mark the plot.

A sample plot may be reduced in size until it becomes a single point and has no area. In a way, the point compares to the quadrat as the line transect compares to the belt transect. Use of points in vegetation analysis was developed in New Zealand as the *pin-point* method (17). This method has many advantages in certain vegetation types and involves use of a frame bearing, usually, 10 pins, which may be raised or lowered in the frame. The frame is placed on the ground and the 10 pins are thrust down one by one, either at an angle or perpendicular to the earth's surface. The plant species touched by each pin is recorded. Hundreds of points can, of course, be recorded by a single investigator in a day, and from the data so gathered both composition and density can be obtained with a high degree of accuracy. Thus, if, on 1,000 points, no vegetation is touched on 300, then the density is 70 per cent. If, of the 700 pins touching vegetation, 350 touch bromegrass, this species forms 50 per cent of the composition. This method has been found to be as accurate statistically as any other method of botanical analysis and is outstanding for use on dense grass stands such as cultivated pastures (19). The similarity between this method and the loop method of transect analysis will be apparent. In fact, points may be used instead of loops.

Charting Vegetation. The vegetation present on plots or transects may be measured, counted, or estimated by several methods. Generally these methods may be classed as either *charting* methods, *listing* methods, or *estimating* methods.

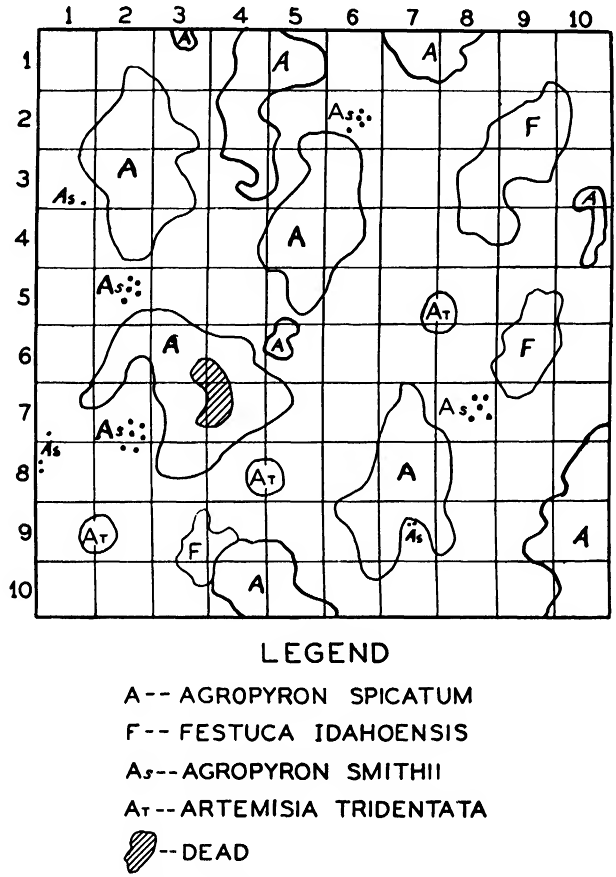

FIG. 52. A meter-square chart quadrat map. Single-stemmed plants such as *Agropyron smithii*, and *Artemisia tridentata* are merely located and not traced. Bunch plants such as *Agropyron spicatum* and *Festuca idahoensis*, however, are delimited accurately and their area can be determined by planimetering.

Charting a transect or quadrat involves making a small map of the location of individual plants on the plot. Such a map may be made by freehand trace from a frame subdivided, generally, into 25 or 100 squares by string, onto a paper similarly divided (Fig. 52), or by means of a pantograph—an instrument designed to map automatically at a reduced scale the traced vegetation clumps (Fig. 53). To obtain the area of the

vegetation, these maps must be measured either by planimeter or by counting squares.

Generally, the basal area or crown area is mapped rather than the top or foliage area. Foliage area varies greatly from year to year with precipitation; therefore changes in basal area are more likely to indicate vegetation response to management.

In studying shrub ranges, plots may be outlined by means of twine strung at the level of the brush by means of tall stakes. The plot may then be subdivided if desired and the plants traced or merely located on

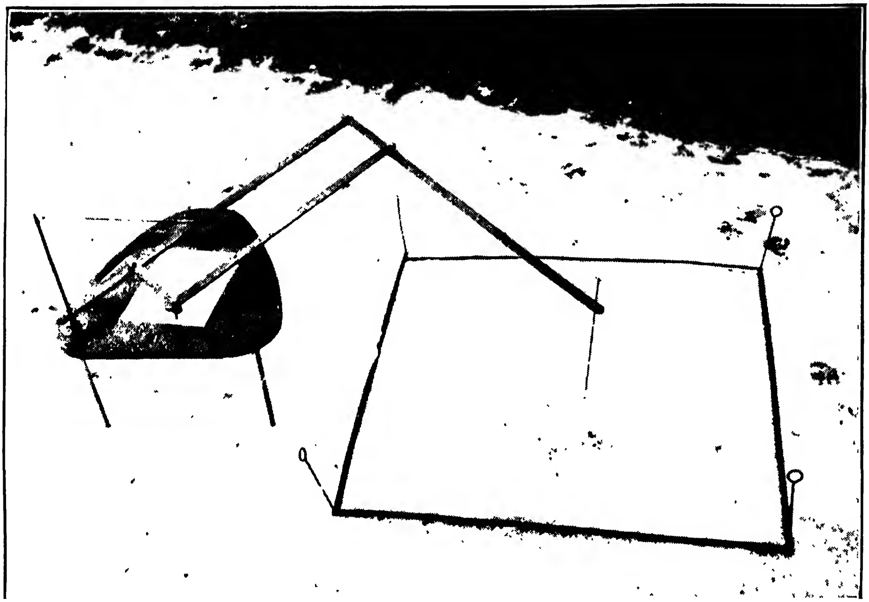

FIG. 53. The pantograph for accurate mapping of vegetation.

a chart and measured. Generally, height and maximum and minimum diameters are recorded for each individual. For low-growing shrubs, the *coordinate* method has been suggested (23) in which shrubs on a transect are charted from an overhead wire frame supported at any desired level by two steel tapes, which are, in turn, supported by adjustable clamps on corner stakes. The frame can be moved lengthwise of the plot along the tapes as the vegetation below is plotted.

A photograph taken from directly above or even from a slight angle gives a readily understood record of vegetation. Oblique pictures are useful for visual evidence of changes in plant cover over a period of years, but they cannot be used for quantitative measurement. Overhead photographs give a much more accurate record of quantity, especially

when taken through a calibrated lens, which records a cross-sectional grid on the negative. Rapidity and freedom from human error are the chief advantages of the photograph. There are, however, distinct sources of difficulty which seem permanently to debar the photograph from absolute accuracy and ease of use. The camera cannot record plants of different heights on the same scale, since plants nearer the lens appear larger. Identification from the photograph of similar-appearing plants is impossible except with detailed field notes. Also, plants forming an overstory preclude the appearance of understory plants in the photograph.

Listing Vegetation. Vegetation may be recorded on a plot by listing for each species any of the following: (*a*) the area occupied, (*b*) the number of individuals present, (*c*) the weight produced, or (*d*) simply whether or not it is present.

The *area-list* method involves determination of the area of each clump of vegetation in the field and listing the areas so obtained either for a plot as a whole or for any subdivision within a plot. Areas in the field may be determined as follows: (*a*) By a ruler called the *diameter rule*. The investigator measures the diameter of a grass clump with this ruler, but it is so calibrated as to read directly the area within the clump so measured. The diameter of clumps that are not round may be determined in several directions and the resulting areas averaged. (*b*) By an angular rule, which is composed of two calibrated arms forming, together, a right angle (Fig. 54). This angular rule is thrust against the base of a plant and the two dimensions measured. The area of the clump can then be approximated by multiplying one dimension by the other. (*c*) By a frame divided into a large number of squares of known area. The area of the clump is then estimated from the percentage of the small squares that it occupies. (*d*) By a steel tape called a densimeter which circumscribes the bunch and reads area direct from the circumference. It can be seen that each of these four methods is subject to considerable error and that none can be applied except to vegetation growing in sharply defined bunches.

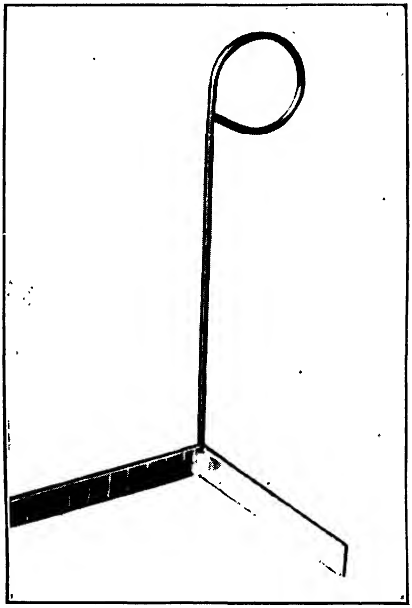

FIG. 54. The angular rule used to facilitate estimation of vegetation-clump areas in small-bunch types of vegetation.

The *number list* involves a count of the individual plants or the number of stems of each species in all or any part of the plot. No attempt is made to convert this to area; rather, the number alone is used as an index to any change in plant abundance. Obviously this method is tedious, and often identification of individual plants or clumps may be difficult.

The *weight list* is the most accurate of all plant-study methods. It consists of clipping all plants at ground level and weighing the yield generally by species. Samples must be dried in order to convert data to a dry basis. For range-management purposes, this method gives a result far superior to any other, for it measures accurately the total herbage production, necessitating only an adjustment according to use factor to convert it to pounds of forage available. It has the further and very definite advantage that it eliminates all estimating. Two decided disadvantages limit its use. Clipping disturbs the vegetation more than any other measurement method, and this major physiological upset makes the plot atypical for further study. Another disadvantage is that forage yield varies more from year to year than does basal area; hence, data are less apt to be representative of normal.

The *species list* is much less used in range work than are other methods because it is not so good as a measure of herbage production. In this method, species are merely listed for presence. If a plant occurs within a plot, it is recorded as present, regardless of whether it is represented by a single stalk or whether it fills the plot. Since it involves a minimum of labor, this method has certain advantages. A large number of plots can be studied in a short time, and the distribution or frequency of occurrence can be determined with accuracy. Such records are excellent in studying plant succession involving removal of some species and invasion of others over a period of years.

Shrub Studies. Shrubs may be marked individually by metal tags or colored stakes, generally numbered. The plants then are measured and changes recorded over a period of years. Death of old plants and appearance of new plants can be noted. Individual branches can be numbered by metal tags and records kept as to change in length, number of branches, utilization by grazing animals, etc., either at short intervals or from year to year.

Shrubs can be studied also by counting annual rings which indicate age. The date at which shrubs invaded can be used to date fires. Numbers of old plants compared to new plants will indicate whether shrubs are increasing or whether they are disappearing. Abundant reproduction of preferred shrubs indicates good range condition, and abundant reproduction of unpalatable shrubs indicates range misuse.

Estimating Range Vegetation. Detailed study of plants to appraise existing conditions generally is infeasible on large land tracts such as

characterize the western range. Estimation therefore is a common method for judging *density* (or *cover*), weight production, and also species composition of the flora. Estimation is a faster, more economical, but less accurate method than measurement. It may be done on small plots subject to statistical manipulation, or it may be done for the range as a whole. The latter is sometimes called "ocular reconnaissance."

Vegetation density or ground cover is determined as an index to volume of forage produced. Ordinarily density is expressed in percentage of ground covered as represented by the projection of all herbaceous plants and all the current year's growth of shrubby plants onto the ground surface, viewed from directly above (Fig. 55). In range work, however,

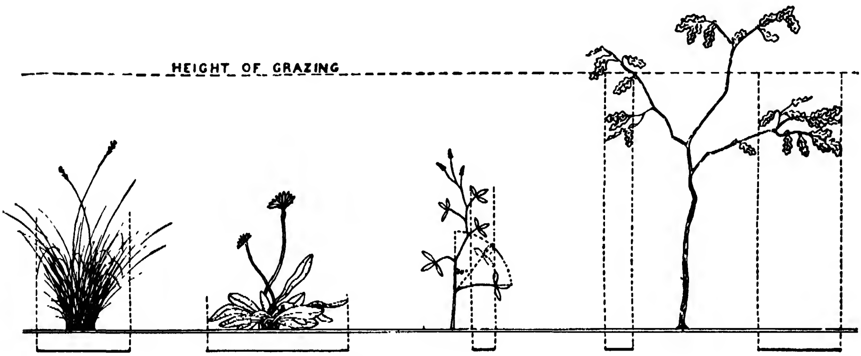

FIG. 55. Methods of projecting vegetation of various types for purposes of density estimation.

density sometimes is recorded in tenths; thus, an area completely covered has a density of ten-tenths, and one only half covered has a density of five-tenths.

Forage density, rather than basal density or foliage density, is used in many range studies. This includes only that vegetation within reach of livestock, generally that below 4 ft. for sheep and 5 ft. for cattle. Vegetation not available to stock, such as that within a dense clump of oak, is excluded from the estimate of forage density. It will be apparent that forage density varies greatly from year to year; hence estimates sometimes are adjusted according to normality of the growing conditions. Season of year and degree of grazing also influence forage density and must be properly considered in the estimate.

The accuracy of vegetation analysis is affected by differences in density concept. Some observers estimate at an angle, which, of course, gives a vastly greater density estimate than when the vegetation is correctly viewed from above. The degree to which clumps should be compressed or spread is likewise confusing. The presence of layers of vegetation,

either of one species growing below another or of one branch growing below another on the same plant, is a major cause of inaccuracy.

Estimating by Plots. Range land usually is subdivided into vegetation types which are studied separately. Careful and complete subdivision results in more uniform and hence more easily estimated types. Forage may be estimated for each type as a unit or individual plots may be used to sample the type.

A convenient plot for estimating is the 100-sq. ft. circle. Such plots may be marked on the ground by use of two rods attached by a 5.64-ft. chain. One rod is thrust into the ground and the second is used to circumscribe the plot. On such a plot, individual species are listed in square feet of density, usually by means of a wire frame of 1-ft. area used as an aid in estimating. On a 100-ft. plot, 1 sq. ft. equals 1 per cent density. From the resulting data both total density and species composition are secured. When the type is estimated by ocular reconnaissance, these two are secured in separate estimates. Ground cover is first estimated; then composition of this cover is estimated independently. Expressing this another way, on plots, the composition is recorded in terms of percentage of ground covered by each species, whereas, without plots, composition is estimated directly in terms of percentage of total vegetation.

Another method of density estimation involves use of density classes, preferably five. These classes may or may not be even-sized. Ordinarily the following might be decided upon:

Class	Description	Density range, per cent
1	Dense	80–100
2	Medium dense	60 - 80
3	Average	40 - 60
4	Medium sparse	20 - 40
5	Sparse	0 - 20

However, on arid-range vegetation where heavy covers of vegetation are almost wholly absent, uneven classes may be used as follows:

Class	Description	Density range, per cent
1	Dense	50–100
2	Medium dense	30 - 50
3	Average	15 30
4	Medium sparse	5 - 15
5	Sparse	0– 5

By this method, hundreds of small plots are randomly located. This may be done by traversing the range and throwing down a small wire hoop, perhaps at each 25 steps. Vegetation within this hoop is quickly placed in one density class. This method, although not precise, is well suited to large areas because of its speed and the large numbers of plots which may be estimated in a short time.

An average density figure can be calculated as follows:

Class	Density range, per cent	Frequency	Average density of class	Product, frequency × average
1	80–100	100	90	9,000
2	60– 80	150	70	10,500
3	40– 60	250	50	12,500
4	20– 40	300	30	9,000
5	0– 20	200	10	2,000
Totals		1,000		43,000

Then,

$$\text{Density} = \frac{43{,}000}{1{,}000} = 43 \text{ per cent}$$

Density as Forage Index. Since there is no accurate means of measuring forage density, there is no means of checking upon the accuracy of density estimates. Further, density has serious fault as an index to forage, because there is insufficient relationship between volume of forage produced and area as expressed by density. A plant covering 1 sq. ft. of ground surface and growing to 6 inches in height has no greater density than another of the same growth habit two or three times as high. However, this difference in height will make a great difference in the amount of forage. The failure of plants to show high correlation between density and volume of forage is marked between different classes of plants, although it is scarcely less within a given class. There may be considerable variation in forage yield per unit of density within a given species, depending upon vigor of growth resulting from a favorable precipitation or favorable site. Table 26 indicates the lack of agreement between the volume produced and density as measured by clipping and weighing the yield from a square foot of 10/10 density of vegetation.

That density is a poor index to yield has been shown by studies in the Southwest (16) where stands of blue grama (*Bouteloua gracilis*) are invaded upon misuse and decreased vigor by other species or by other grama plants and density actually increases. When proper use is initiated, density must be reduced by death of the weaker plants before the stand can increase. Low production per unit of density results from over-

TABLE 26. DRY-WEIGHT PRODUCTION, GRAMS PER ESTIMATED SQUARE FOOT, OF SEVERAL IMPORTANT FORAGE PLANTS. DENSITIES OBTAINED BY AVERAGING ESTIMATES OF 27 INDIVIDUAL FIELDMEN

Plant Species	Yield per Square Foot, Grams
Aspen (*Populus tremuloides*)	61.0
Snowberry (*Symphoricarpos* sp.)	49.6
Geranium (*Geranium* sp.)	113.3
Sweet clover (*Melilotus alba*)	208.8
Giant ryegrass (*Elymus cinereus*)	248.1
Bluegrass (*Poa pratensis*)	16.4

crowding, for areas with low precipitation cannot support a large number of plants per unit area.

Attempts have been made to improve upon the density method by use of height. The density of each species is multiplied by a height factor to convert to forage volume. The imperfect correlation between height and volume, however, makes this method virtually useless. Likewise, multiplying density by a weight index has not proved feasible. By this method, average weight per unit of ground cover is determined for each species to arrive at a conversion factor. Variability resulting from season and site, however, make this inaccurate although better than density alone.

Estimating Forage Weight. Because of the problems involved in the interpretation of density in terms of forage volume, a method of estimating weight directly has been advanced. This method was used by Jones and Thomas in 1933 (19) and consists of direct estimation of the weight of green herbage of each species within small plots. Estimations are verified and adjusted by checking the estimate by clipping, separating, and weighing herbage on trial plots. Samples of herbage can be dried to convert estimates to a dry-weight basis. The fieldman usually carries in mind a certain unit for each species of perhaps 10 to 500 grams, which he is trained to visualize. This he uses as a measuring stick in field estimates.

This method is somewhat more subject to error of judgment than density estimation, but it has the advantage of yielding data directly in the terms desired. It has a further advantage in that it is subject to accurate check since weight can be measured accurately. Inaccurate individuals can be eliminated from the study crew, and consistently high or low estimators may be assigned a conversion factor whereby their estimates may be brought to standard.

USE OF ENCLOSURES IN RANGE STUDY

An enclosure is a study area which is enclosed by a fence. It may be ungrazed or grazed by specific kinds or numbers of animals to the exclu-

sion of others. Sometimes, four hurdles or panels are used for enclosing an area from grazing. These structures, being movable, are ordinarily used in temporary utilization and regrowth studies. Generally, a hurdle or panel plot is small, often only about 10 ft. square. Temporary enclosures made of triangular mesh wire enclosing 3 to 5 acres of land have proved valuable in grazing studies. This wire is stretched by zigzagging on steel posts (Fig. 56), and the pen is easily moved by two men in a single day.

FIG. 56. A movable grazing enclosure of net wire zigzagged between steel posts but not attached is used to form 3-acre pastures for sheep-nutrition studies on desert range.

Protected Enclosures. In the protected enclosure the area is enclosed and protected from domestic stock, game, and sometimes rodents. The object in such an area is to determine the conditions that obtain under complete protection as compared with the results of grazing on comparable adjoining areas. This comparison may be made visually, or it may be detailed plot data secured within the enclosure. Greatest value can be secured only by detailed study, although general conclusions may be of inestimable value in determining grazing procedures. It must be remembered that absolute protection of a range is an index to absolute protection only and not to conditions that might be expected with proper grazing.

Partly Protected Enclosures. Where two kinds of animals graze the same area, it may be necessary, in order to determine the effects of the

different kinds, to construct enclosures that permit the entrance of one kind of animal while protecting the area from another. In studying the effects of forage consumption by rodents, enclosures of wire that hold out domestic stock give a basis for separating the grazing done by the stock from that by the rodents. Completely protected plots must, of course, be established for comparison in the same areas. The forage use on the open range is indicative of the feeding habits of all the animals,

FIG. 57. The area to the left is open to deer which easily jump the low log fence. Abundant grass but no aspen reproduction mark this area. The area to the right is open to cattle and deer. Here forage is almost entirely consumed. In the distance can be seen an area marked by heavy aspen reproduction from which deer and cattle are excluded, details of which are shown in Fig. 58. These areas are Forest Service study plots.

while the partly protected plot indicates the forage use by the rodents. The difference between this and the total forage use indicates the amount consumed by the domestic livestock. Such a segregation can be effected with game and domestic animals as well. An enclosure with a fence 4 ft. in height, especially a pole fence, is sufficient to hold out domestic stock, but it offers little in the way of a barrier to game animals such as deer. There is one consideration that may affect such determinations, and that is the tendency for the animals not excluded to congregate in the partly protected area. It is highly possible that, especially on heavily grazed ranges, the forage conditions will be sufficiently better within the partly

protected plot to make it more attractive to the animals that can gain entry. Such possibilities must be taken into consideration in analyzing data from partial enclosures. Figures 57 and 58 show a partial enclosure.

Grazed Enclosures. Grazed enclosures may be established in order to determine the effects of a known degree of grazing. Thus, a certain number of rodents, game animals, or domestic stock may be confined to an area in an effort to arrive at the actual effects upon range land grazed

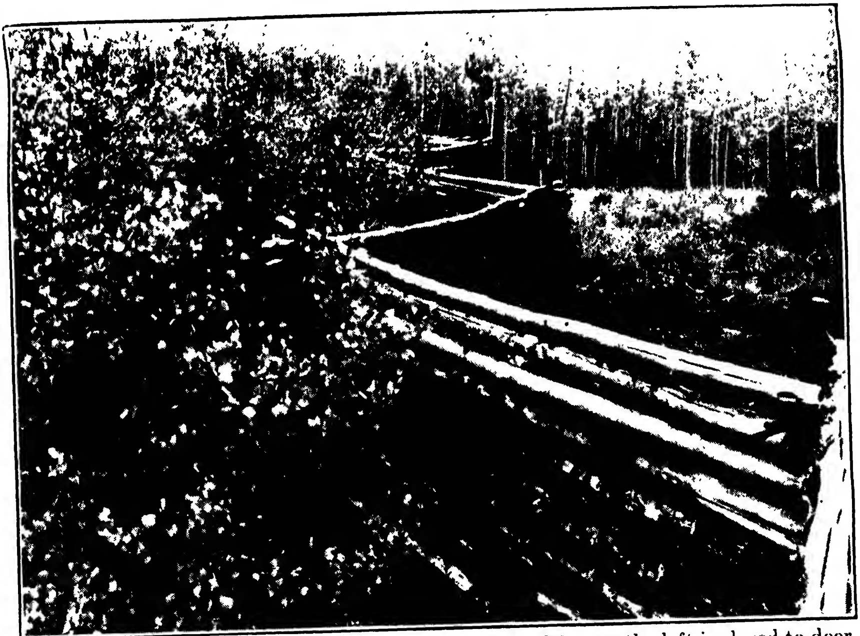

FIG. 58. The area to the right is open to deer grazing. That to the left is closed to deer. Within the 8-ft.-high enclosure is an astounding growth of aspen reproduction; outside there is none.

at various intensities. These are especially important in studies of the effects of grazing upon watersheds.

Size of Enclosures. The size of the enclosure is an important consideration. No exact rule can be given that will apply to all situations. The small enclosure has probably been used far more than its merit justifies. Unless space and funds permit of a large enclosure and a carefully planned project, it had best not be attempted, since the false conclusions drawn from poorly regulated demonstrations often outweigh the benefits. Size will be affected by the kind of vegetation, the kind of animal, the expense involved, and the intensity with which the effects are to be studied. It is, however, possible to suggest general rules that may be helpful in establishing such areas.

A minimum size for any area would be, perhaps, ¼ acre and would increase upward to several acres. It is especially important that the area be large enough to afford a suitable index to normal conditions, for the possibility of a small area being influenced by the presence of the fence is a matter that must be considered. For example, plant distribution may be somewhat affected by the presence of a fence. Tumbling weeds, such as the Russian thistle, which blow across fields and thus scatter their seed, may catch on the fence and so not normally seed a small fenced plot. The absence of the weed in such areas might be falsely attributed to protection from grazing.

On small plots, drifting snow or soil may accumulate against the fence and influence the results throughout a plot of less than ¼ acre in area. Grazing may induce runoff or soil movement, the influence of which may extend into small plots, even though they are not grazed (5).

Similarly, a small plot, fenced against domestic stock, for that very reason may become more attractive than ever to wild animals or insects whose activities greatly falsify the results. Studies in Colorado (5) involving panel enclosures showed that, where jack rabbits were numerous, areas grazed by cattle had consistently higher yields than those not grazed. Pellet counts showed almost twice as many rabbits had grazed on the enclosed plots as on open ranges, a difference sufficient to nullify entirely the results. Such a reaction would, of course, be minimized on very large enclosures.

Enclosures where animals are confined are of value only if they are of sufficient size to prevent any unusual activity of the animals, which will be induced by too close confinement. Such enclosures must, then, be of sufficient size to permit the usual travel and activities of the animals to be studied. In a too small area, the excess trampling by large animals or burrowing by rodents may give a greatly distorted picture. In such small areas, the normal migration of the animals, especially the wild animals, may be interfered with and hence the results nullified.

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CHAPTER

RANGE INVENTORY AND CONDITION CLASSIFICATION

A major problem in range-land husbandry is appraisal of the forage resource and determination of the livestock grazing capacity of the land. Stockmen follow a profession that is centuries old. Through daily contact with the range, some have obtained great knowledge of its potentialities.

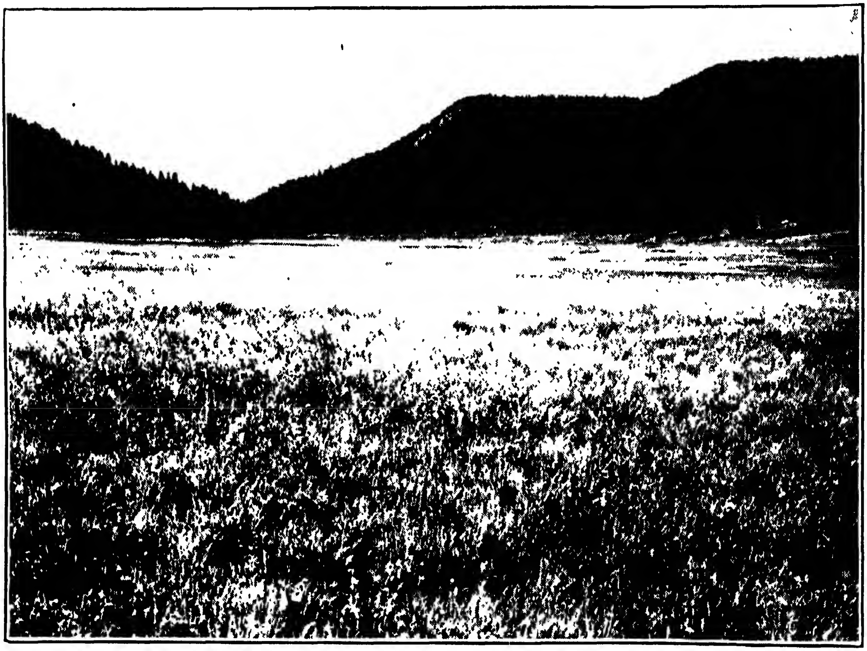

FIG. 59. A grass type characteristic of the dry meadow or 2D type found in high mountains of the West.

However, some, through lack of observation have failed to acquaint themselves with the facts essential to good management. Others, because of economic pressure, have ignored the obvious and have gambled with excess stocking to fight a losing battle against nature. These problems have given rise to efforts to take inventory of the range resource to determine a proper and safe level of stocking and to provide a record of vegetation and vegetation changes.

RANGE MAPPING

Type mapping is one of the most important phases of range inventory, the completed map being of great value in administration and indispensable to a complete range-management plan. A technician who has never seen the land can obtain from the map information on range adaptation such as season of use and potential productivity. If the map shows land contour, which determines to a large extent the natural movements of livestock, suitability to various kinds of animals will be apparent.

The range map always shows vegetation types. A *type* is a more-or-less distinct vegetation unit which may be delimited on the basis of aspect, composition, or density. A breakdown within the type based upon the latter two is sometimes called a *subtype*. Subtype lines often are located along fences or ridge tops to simplify management planning.

An interagency committee has accepted a standard set of grazing types to be used in range inventories (10). Although these are widely used, they unfortunately are based upon a number of entirely different ecological criteria (8).

The Major Grazing Types. Eighteen types are recognized as follows:

Type number	Name	Standard map color
1	Grassland (Figs. 11 and 13)	Yellow
2	Meadow (Fig. 59)	Orange
3	Perennial forb (Fig. 60)	Red
4	Sagebrush (Figs. 21 and 61)	Brown
5	Mountain brush (Figs. 27 and 29)	Olive green
6	Coniferous tree (Fig. 62)	Dark green
7	Waste (ungrazed)	Blue-green
8	Barren	Colorless
9	Piñon-juniper (Fig. 30)	Light green
10	Broad-leaved tree (Fig. 32)	Pink
11	Creosotebush (Fig. 45)	Bottle green
12	Mesquite (Fig. 25)	Yellow earth
13	Saltbush (Fig. 22)	Slate grey
14	Greasewood (Fig. 23)	Royal purple
15	Winterfat	Light tan
16	Desert shrub (Fig. 63)	Dark tan
17	Half-shrub (Fig. 43)	Wisteria
18	Annuals (Fig. 20)	Red terra cotta

Mapping Technique. Almost all range mapping is now done by use of aerial photographs because of the great accuracy and generally low cost. Preferably, photographs are taken to the field and, by visual comparison,

FIG. 60. The perennial forb type in the foreground is dominated chiefly by *Geranium fremontii.*

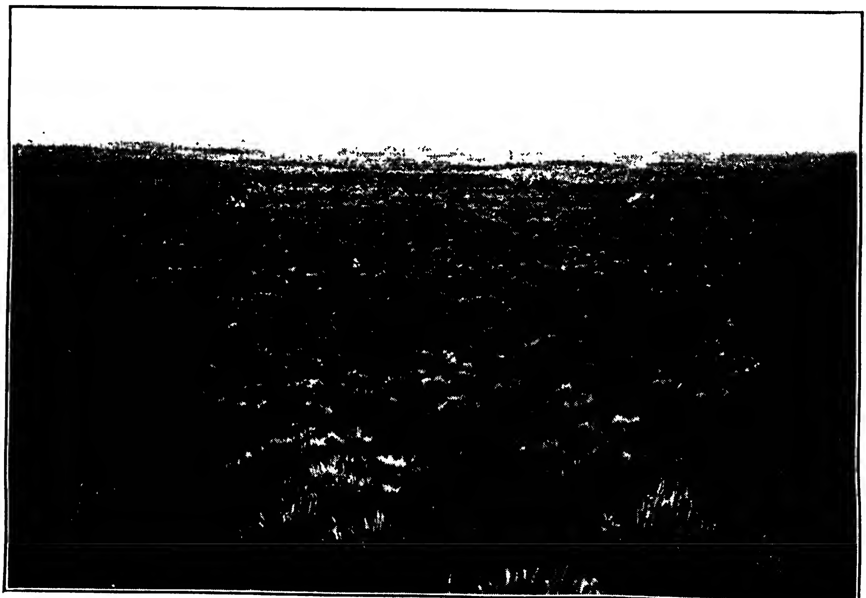

FIG. 61. A sagebrush type dominated by *Artemisia filifolia* and *Sporobolus cryptandrus.* This type occupies large areas of the Southern Great Plains. (*Photograph by F. W. Albertson.*)

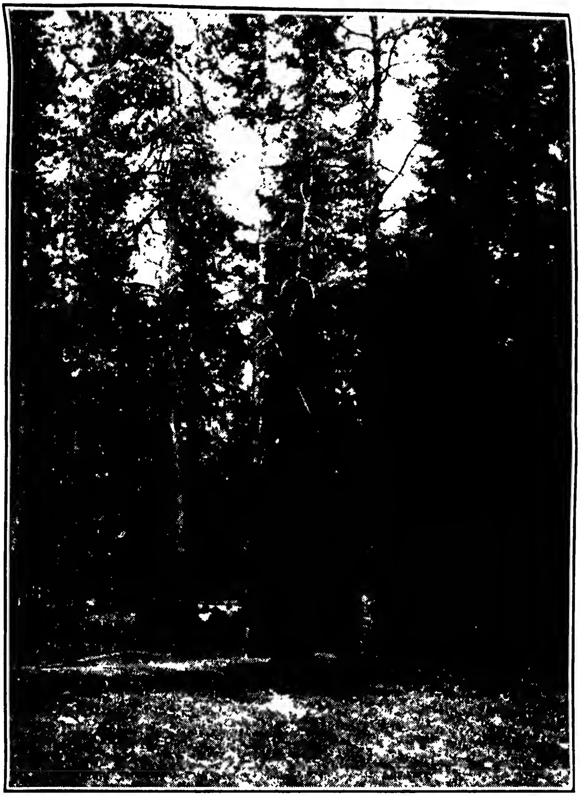

FIG. 62. A typical type 6 dominated by open *Pseudotsuga taxifolia* but containing many grazable forbs and grasses as an undercover.

FIG. 63. Mixed semidesert shrubs form a typical type 16. The dominant species is bur sage (*Franseria deltoidea*) and the Joshua tree (*Yucca brevifolia*) can be seen in the distance.

type lines are located and dotted upon the photograph (Fig. 64). This *may* be done on the *contact print* as it comes direct from the negative or on a mosaic. The *mosaic* is a large composite picture assembled from selected portions of a number of contact prints, only the relatively undistorted center of each being used.

FIG. 64. A section of aerial photograph showing dotted type lines and write-up sheet numbers for each type as drawn in the field.

Field typing sometimes is done directly upon a planometric map. The highly accurate *planometric map* is a compilation from the photographs after they have been oriented by a complex system of radial control. The contact prints are assembled in correct alignment by marking many known points on each and orienting these with reference to the center of the photograph. By use of a scheme analogous to common triangulation, the prints are adjusted so that each point is in its proper

position with reference to at least three others. Next, the photograph is projected upon a map, and desired features are drawn.

The field mapper delimits, usually directly upon the contact print, the types from their appearance and location with reference to cultural and topographic features (Fig. 64). The use of two photographs and a pocket stereoscope is most helpful, especially to beginners, in properly visualizing and reading photographs in the field (1). A well-trained man has much less need of the instrument but can benefit from use of paired photographs to give perspective. Beginning students often have difficulty in the interpretation of aerial pictures, but they soon learn to distinguish the various types and topographical characteristics.

Large photographs give excellent detail for intensive mapping, but photographs as small as 2 inches or even 1 inch per mile have proved very satisfactory for less intensive studies.

Although the pictures cannot be depended upon to show such features as fences and water holes or to distinguish similar types of vegetation, they do call to attention many items that would otherwise be missed. It is best, therefore, to make field type lines directly on a photograph, and to transfer this information later onto the more accurate planometric map.

It is important to locate section corners in the field and mark them, with reference to the pictured detail, direct upon the prints. The adjusted land grid then can be superimposed upon the finished map. A pin may be thrust through the print and notes placed on the back of the print as a means of marking section corners.

THE RANGE-MANAGEMENT MAP

Range-survey maps usually are drawn to a scale of 1 or 2 inches to 1 mile. Type lines are dotted to distinguish them from other features. The map includes such improvements as water developments, fences, corrals, driveways, roads, trails, buildings, and, in some instances, salt grounds, all of which are important to administration plans, and as much of such information as topographic lines, ledges, streams, and lakes as can be included without confusion. Artificial features, such as improvements and type lines, may be placed on overlay sheets to reduce confusion. Generally, type designations, including area and capacity, and distribution or management unit lines, are placed on an overlay, for they are more temporary than other features.

Grazing Type Designations. In the field, range types are classified as belonging to one of the previously described types and are assigned a type number. Further, they are characterized by dominating species whose names, usually abbreviated, follow the type number. Usually two to three dominating species are included and, occasionally, a class of

plant where several species are of about equal importance. Thus the symbol 4-Atr. Aco. would indicate a sagebrush type dominated by *Artemisia tridentata* and *Atriplex confertifolia*, whereas the symbol 4-Atr. Gr. would be a sagebrush type dominated by *Artemisia tridentata* with an undercover of mixed grasses.

Though the procedure is not standard, a figure showing the area and capacity of the type generally is placed under the type symbol. The capacity figure is given in forage acres or cow-months or sheep-months, though sometimes the forage-acre factor is used. Thus,

$$\text{4-Atr. Aco.}\atop{\dfrac{640}{210}}$$

might designate a sagebrush type of 640 acres supporting 210 cow-months. All maps should carry a legend showing the exact interpretation of data (Fig. 65).

Area and Grazing-capacity Compilation. Carrying-capacity data may be compiled by any of a number of methods. On public lands, it is desirable to summarize on the basis of allotments grazed by each permittee or by units or compartments within each allotment. Occasionally, area and capacity are calculated for each township or section. Increasing importance is being given by federal grazing agencies to breaking down carrying-capacity figures by landownership in the case of private land and by administrative control in the case of public lands for the purpose of perfecting land-use practices in areas of mixed ownership. Alienated lands, i.e., lands other than federal but intermingled with federal, are calculated separately. For clarity, areas and capacities of each subdivision are entered on the map in various manners to indicate the portion of the area to which each applies. Total acreage and grazing value of an administrative unit, i.e., an area having a common management policy, may be shown thus: $\left[\dfrac{907}{170}\right]$. Acreage and grazing-value figures for the section as a unit may be shown thus: $\left(\dfrac{640}{81}\right)$. Those for a portion of a type within the section or unit may be shown thus: $\dfrac{38}{9}$.

ESTIMATING GRAZING CAPACITY

Weather in western United States is subject to great annual variability, and annual forage production tends to vary even more, being correlated especially with volume and seasonal distribution of precipitation. The production may be two to three times as much one year as another on perennial forage; on annual vegetation it may be ten times as much one

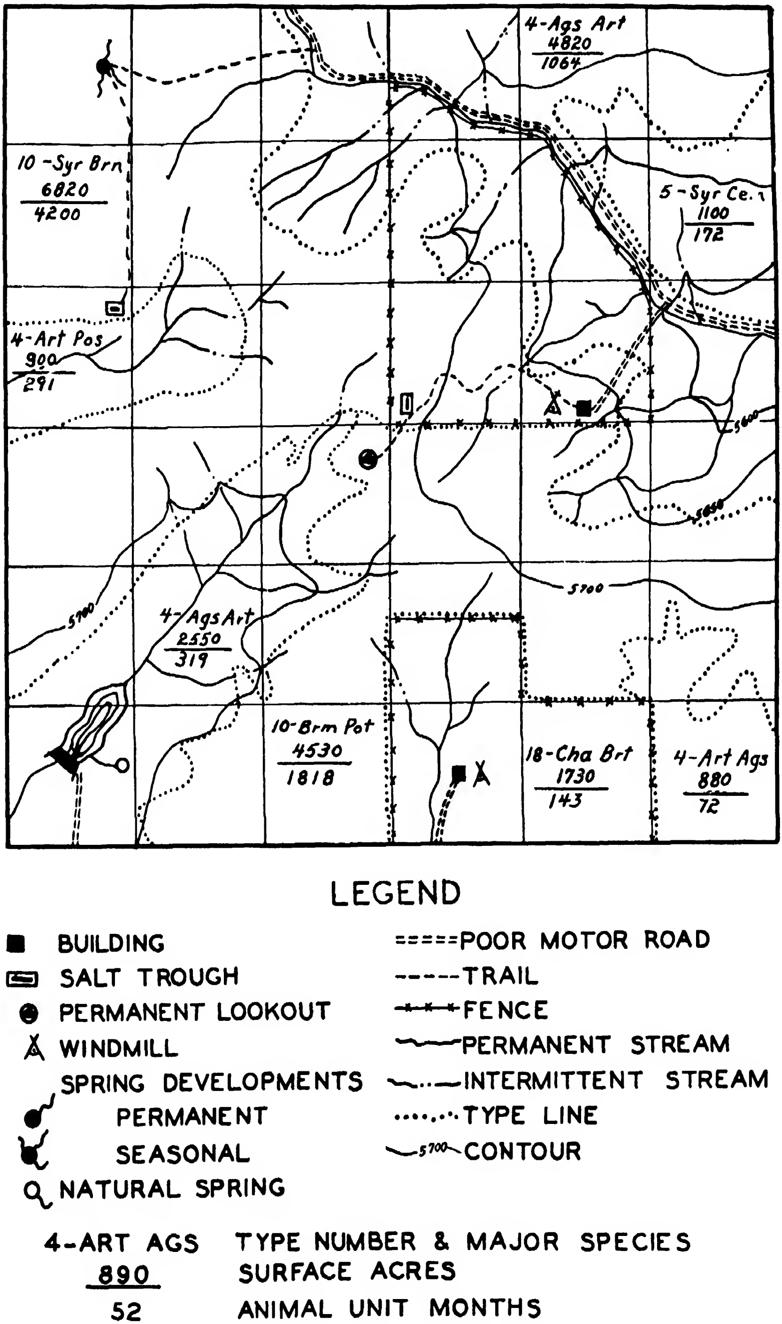

FIG. 65. A range-survey map, compilation for which is based upon the type as a unit.

year as another. Such variation necessitates ultraconservative use in productive years or flexibility in number of livestock from year to year. In years of low production, ranchers on private lands can adjust livestock numbers through sale or perhaps can provide supplemental feed, thus reducing the animal-months of grazing the range receives.

Great variation of stock numbers permitted on federal lands is infeasible, however. Federal range managers are forced to grant long-term permits for specific livestock numbers. Specific numbers are demanded by the livestockgrowers to stabilize the industry, and only through occasional and minor adjustment in the duration of the grazing period in a given year can grazing be adjusted even slightly to annual production of forage. The problem of the administrator, then, is one of designating a specific number of animals which can graze on a unit of land more or less indefinitely without injury to the land and which he designates as the grazing capacity of that land (19).

Grazing capacity, then, has come to be regarded as the maximum animal numbers which can graze each year on a given area of range, for a specific number of days, without inducing a downward trend in forage production, forage quality, or soil. Perhaps it should be pointed out that this is, in many ways, a wasteful concept of grazing capacity, because, if forage is to be adequate in years of low production, then there must be excessive amounts of ungrazed forage in years of high production. If economically full use is made of forage in good years, overgrazing must result in poor years. We have no reason to believe that overuse in one year can be compensated by underuse in another year; hence, stocking that would result in correct use in the average year does not appear to be the answer. Consequently, the practice generally is to stock so as to prevent overutilization of the available forage in all but the most extreme drought.

Early attempts to solve the problem of grazing-capacity determination were pointed toward a direct examination of the vegetation. Two general field procedures were developed. The results obtained by the two methods differed only as the use of plots affected the vegetation estimate. The differences were procedural only and differed in no basic principle.

Ocular Reconnaissance Method. Essentially, the procedure is to make a forage analysis by plant types, each species of plant being listed (occasionally only the most important ones) on a type sheet, the percentage of total composition that it represents indicated, and the forage density of the type estimated (Fig. 66). By multiplying the use factor of each species by its percentage of the composition and summing these products, the *weighted use factor* is obtained. This is then multiplied by density[1] of the type cover to arrive at a forage index (*forage-acre factor*) expressing the part of a range that is covered with available vegetation which can be eaten in entirety by livestock without damage. Thus, an

[1] For density determination methods see pages 155–158.

acre only half covered with vegetation (density = 0.5) of which only half is properly edible to stock (use factor = 0.5) would have a forage index or forage-acre factor of 0.25, or the equivalent of ¼ forage acre. The *forage acre* is a theoretical acre totally covered with vegetation, all of

RANGE SURVEY FIELD SHEET
(Reconnaissance Method)

Ranching unit ...Bar X... Date ...July 17, 1955...
Examiner ...John Doe... Location ...T. 6 N... R. 5 E. ... Sec. 24
Type ...4 – Atr. Aco.... Field sheet No. ...D-24...
Avg. density ....14... Avg. % Pal. ....259...
F. A. factor ....0363... For ...Sheep... (C. and H or S. and G)

Grazing Capacity: F. A. factor ....0363... × ...1000... Surface acres = ...36.3...
Forage acres ÷ Forage acre allowance ....1... = ...363...
Animal months ÷ 3 = ...121... Animal units.

TYPE WRITEUP
PRINCIPAL VEGETATION SPECIES

Grasses, 8 %	% Each Spec.	% Palatable	Weight Palatable	Weeds, 42 %	% Each Spec.	% Palatable	Weight Palatable	Browse, 50 %	% Each Spec.	% Palatable	Weight Palatable
Wheatgrass	4	60	.024	Yarrow	10	50	.05	Sagebrush	33	10	.033
Ricegrass	4	80	.032	Thistle	32	25	.08	Saltbush	16	20	.032
			.056					Winterfat	1	80	.008
							.13				.073

.056
.13
.073
.259

(OVER)

FIG. 66. Data sheet used in ocular range survey, showing the method of computing the forage-acre factor.

which is properly usable by livestock. When the forage-acre factor is multiplied by total acres in the type, total forage acres is obtained. Shown algebraically, the computation may be summarized thus:

I. Summation (percentage species composition × use factor of each species) × forage density of the type = forage-acre factor
II. Forage-acre factor × surface acres = forage acres

Plot Method. In the plot method (17), forage inventory is restricted to specific plots, generally 100 sq. ft. in size, and these alone are used for the capacity estimate. They are usually circular in shape and are marked on the ground by a rod or chain 5.64 ft. long, used as the radius of the circle. The number of plots necessary in any type depends upon its size, the homogeneity of the vegetation, and the intensity of the survey. Sampling accuracy increases as the square root of the number of plots

RANGE SURVEY WRITE-UP SHEET

Project Utah Co., Utah — Transect No. D - 24
Date July 17, 1948 — Location 6N 5E 24 (T. R. Sect., or Aerial Photo No.)
Examiner John Doe — Timber Douglas fir (Composition) poor (Condition)
Type 4 Atr Aco — none (Reproduction) (Density) (Age)
Forage Density .1437 — Slight (Injury) porcupine (Cause)
Total Density .1437
F.A.F. .0370 For Sheep (C, S, C.U.)

Utilization cuts: Slope 0 % Timber 0 % Rocks 0 % Erosion 25 %
Lack of water 10 % Unstable soils 0 % Total cut 35 %

PLOT NUMBER											Total Sq.ft.	Ave Dens.	Times Pal.
Artemisia tridentata	8	0	6½	5	4	3¼	6	2½	0	13	48¼	.0482	.0048
Atriplex confertifolia	2½	1	0	5	6½	2	3	3¼	1	0	24¼	.0243	.0049
Eurotia lanata	0	0	1¼	0	0	0	0	0	0	0	1¼	.0012	.0009
Agropyron spicatum	0	¼	3½	0	0	¼	½	2	0	0	6½	.0065	.0039
Oryzopsis hymenoides	0	0	0	0	0	½	0	0	3½	2	6	.006	.0048
Achillea lanulosa	6	0	1½	0	0	0	0	2¼	2	1¾	13½	.0135	.0067
Salsola pestifer	5½	6	7¼	2	0	9½	2	4	5¾	2	44	.044	.0110
												.1437	.0370

FIG. 67. Data sheet used in plot surveys, showing the method of computing the forage-acre factor.

taken, though different types of vegetation require different numbers of plots for a given degree of accuracy (3). Fewer plots need be used if large types and types of low grazing capacity are less intensively sampled.

As in the ocular method, vegetation is estimated; however, individual species are listed in square feet or, on 100-ft. plots, in percentage of ground covered rather than percentage of total vegetation (Fig. 67). The sum of the mean density estimates of all species is the forage density of the type. Mathematically, the calculations required are

Summation (average per cent of ground covered by each species × its use factor) = forage-acre factor

Originally it was thought that the forage-acre factor would reveal actual grazing values and that it would be comparable to other feed units. However, it has been shown that forage production per unit of plant density varies so tremendously between species, and indeed even within the same species, that the value of the range analysis made by these techniques is questionable. Moreover, the variation in estimates by different investigators, and even the same estimator at different periods, is considerable (15). When these inaccuracies are coupled with errors of equal magnitude due to the difficulty of ascertaining correct use factors, it is evident that little reliance can be placed upon grazing capacities arrived at by either survey method.

Another factor contributing to the decline in popularity of range reconnaissance is that as the period of grazing supervision over public lands increases, actual stocking records become more reliable, and these, together with an appraisal of the range by utilization checks or by condition observations, serve as a guide to grazing capacity. Supplemental data gathered during the range survey (Fig. 68) may be of as much or more value in management planning as the carrying-capacity data.

Utilization Cuts. Certain factors that characterize a range influence the use that can be made of the forage. On excessively steep slopes, animals cannot or will not fully utilize all the forage. Ranges that are rocky or distant from water are used incompletely. For purposes of conservation, grazing may be reduced below the capacity of the forage, as, for example, to protect young timber trees from damage, or to protect erosive soil from excess distrubance. Such reductions are known as *utilization cuts.* These conditions may be temporary, and some may be overcome by developing water or building trails. Hence, it is not desirable to reduce the forage-acre factor, which should give a true picture of the forage resources. An adjusted forage-acre factor is derived as follows:

$$\text{Adjusted forage-acre factor} = \text{forage-acre factor} - (\text{forage-acre factor} \times \text{utilization cut, per cent})$$

Carrying capacity based on the adjusted forage-acre factor may change with a change in forage production, a development that might change the utilization cut, or a change in use such as a seasonal change or a change in kind of stock.

Utilization as an Index to Grazing Capacity. Utilization surveys have sometimes been used to arrive at carrying capacity of ranges. The procedure requires a knowledge of the actual amount of use in terms of animal-days or animal-months. The known use is related to the degree of utilization that resulted from it, and the amount of forage remaining can then be stated in terms of animal time remaining. Thus if 100 animals in 3 months (300 animal-months) results in 30 per cent utilization, and if

TYPE COMMENTS

Current Forage Utilization: (Check after one) over ✓ proper .... under ....

Plant Vigor: (check after one) poor ✓ fair .... good ....

Range Conditions: (check after one) poor .... fair ✓ good ....

Relative Productiveness of Site (check after one) low .... ave .... high ✓

Watering Places:

Kind	Distance	Adequacy, need of development, season
Well	on type	Good condition, yearlong, adequate
Spring	1 Mile	Undeveloped, Probably spring season only

Poisonous Plants:

Species	Abundance	Need for eradication, seasonal adjustment, class change
Astragallus albo	rare	Doubtfully dangerous

Kind of stock best suited to range: (check after one or more) cattle ✓ horses .... sheep .... goats ....
Proper Grazing Period: (check 1 or more) spring .... summer ✓ fall .... winter .... yearlong ....
Wildlife: *Game, predators, and rodents.*

Species	Abundance	Need for control, evident damage, etc.
Coyote	very abundant	Would be serious with sheep
Ground squirrel	abundant	Poisoning advisable, especially on section 12

Soil Erosion (check after one or more)
Explanation of gully terms: Occasional gullies are gullies more than 100 feet apart. Frequent gullies are gullies less than 100 feet apart. Shallow gullies are those easily crossable by stock. Deep gullies are those deep enough to interfere with stock movements.

Sheet Erosion Evident ....
Gully Erosion
Occasional gullies, shallow ....
Occasional gullies, deep ....
Frequent gullies, shallow ✓
Frequent gullies, deep ....
Wind Erosion
Deposition evident ....
Removal evident ....

Soil Texture (to six inches deep)
Check in appropriate blocks

		Gravelly	Stony
Light			
Medium		✓	
Heavy			

Alkali (check if evident) ....

Slope in percent: (circle appropriate classification) 0 to 5, 6 to 10, 11 to 20, 21 to 40, 41 to 60, 61 to 80, 81+

Additional type comments ....
Serious over stocking evident. Might be overcome in part by deferred grazing. Stock should be kept down at lower elevations until July 1 by drift fence or possibly by deferred salting.

FIG. 68. Sample data sheet which accompanies the vegetation analysis of each type in the range survey.

60 per cent utilization is correct, it is estimated that full use would result from 600 animal-months of grazing. The difficulties in this approach lie in our lack of knowledge of what represents proper use as well as in the inadequacies of the methods of determining utilization (see Chap. 6, page 137).

RANGE-CONDITION CLASSIFICATION

The term "range condition" to the range manager has a special meaning and relates current condition of the range to the potential of which the particular area is capable. It should not be confused with immediate availability of succulent forage, which may be a reflection of general weather conditions for that season or year. The Department of Agriculture has used the term in the latter sense in periodic reports of western range condition. If rains have been frequent and temperatures favorable, ranges are good under this usage. The range manager attempts to look beyond the immediate greenness of the herbage and to discover whether the plants, which characteristically should grow in a particular situation, are present and in good vigor. He notes the quantity of each species present as a basis for determining the degree to which the productivity of the range has been impaired. Range condition in this sense is best described as the state of health of the range.

Range-condition analyses, though little used during the early years of the development of the science of range management, have become a common basis for adjustment of stocking figures and revision of management plans. The basic concept was not a new one, for it had been recognized early by F. E. Clements. Sampson (14) proposed that the story of range use could be read in the plant cover that was to be found upon the range, for, as he pointed out, continued heavy use results in changes in the plant cover of an area. Although the general idea was widely accepted by range ecologists, a considerable period elapsed before the principles enunciated were applied generally and the stages in range deterioration were classified for other areas of different composition.

Range-condition classification is based upon the theory that vegetation is the product of environment—a cause-and-effect relationship. Environmental factors of most direct importance to range vegetation can be classified as climatic, edaphic (soil), and biotic, chiefly grazing by animals. Fire also must be considered as an important habitat factor locally. Because of these factors, much of the West may never have reached climax status, but other parts have reached the stable climax only to regress because of a change in environment, such as increased grazing or fire (Fig. 69). Thus deviation from climax may involve past use, but time must also be considered. Time is necessary for vegetation to reach climax initially; and time is necessary for the return to climax following disturbance. Sometimes the great time involved makes climax an impractical objective of management. Occasionally a high-producing subclimax may be a satisfactory range, and economic factors make it unwise to manage so as to return to the theoretically possible climax. The management objective should be clearly outlined, but only after careful

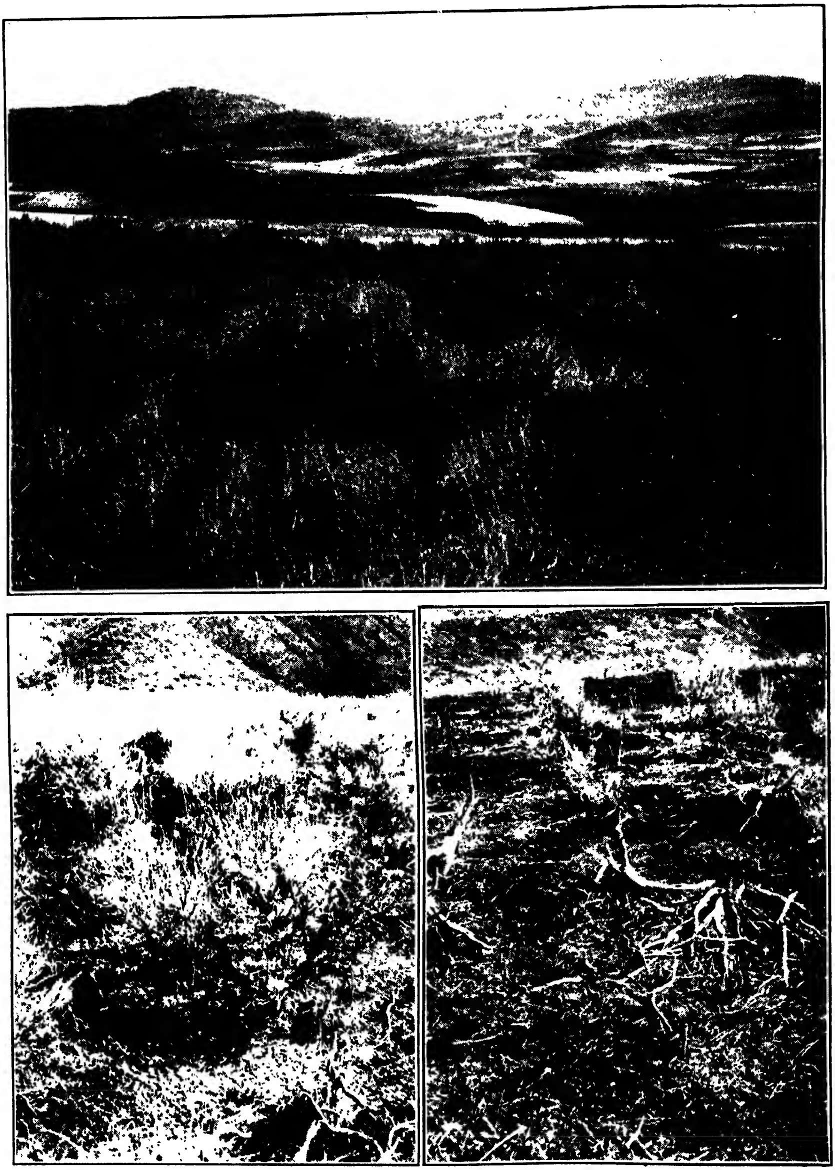

FIG. 69. Above is a protected corner in which sagebrush (*Artemisia tridentata*) and wheatgrass (*Agropyron spicatum*) grow in near climax association. With severe grazing the more desirable grass disappears, leaving only the undesirable sagebrush, as shown in the lower left photograph taken near by. Even the sagebrush will be killed, as shown in the lower right photograph, and low-value plants will invade if grazing is unusually severe. This condition usually exists only on bedgrounds, driveways, or other areas of exceptional concentration.

study of environment and current and potential productivity of the site.

Determining climax or normal conditions is difficult and sometimes almost impossible. Protected areas, conservatively grazed range, ungrazed fence corners or cemeteries, and such indicator areas must be sought out and studied carefully. Certainly it is unwise to outline management objectives before the site potential is well understood.

Early Use of Classification. The first attempt at defining generally applicable range-condition classes was in 1935. This system used in early Soil Conservation Service surveys in the Northwest Region provided five classes in which the condition was related to the climax (13, 16, 18). These classes were in reality but stages of plant succession or regression. The five classes were described as follows (20):

Class 1. Climax vegetation, not overgrazed to cause any successional change.

Class 2. Predominantly climax vegetation but invaded by perennial forbs and better annuals.

Class 3. Climax vegetation present but not dominant. Palatable plants destroyed and replaced by less valuable or annual plants. Climax vegetation can be brought back by protection.

Class 4. Climax vegetation absent. Some valuable plants present, but largely non-palatable or low-value vegetation.

Class 5. Climax vegetation absent. Land worthless for grazing either because of lack of vegetation or because of low palatability of vegetation.

Since that time, there has been increasing use of the method, and many ramifications have evolved as the concept was applied in different areas by different workers.

Humphrey (7) has traced the early history of the use of range-condition surveys as an approach to range-use adjustments and showed positive correlation between condition class and grazing capacity (9). It was early recognized that species composition was an important index to condition class.

Species composition appears to be a better index to condition than is density. Unfortunately, tools available to the range manager for vegetation analysis are so limited that it is difficult to detect minor changes and thus increase our knowledge of behavior of individual plants within the community. Unquestionably succession induced by too heavy grazing and that resulting from recovery may follow different paths depending upon climatic, edaphic, and perhaps other factors. Moreover, composition changes may occur within a range, even though its condition remains the same, and it is necessary to know about these natural changes if composition criteria are to be applied intelligently.

Species-composition Method of Condition Analysis. Use of species composition as an index to range condition involves ecological analysis of

the climax and successions leading to and away from the climax. This must be done for each climatic entity and perhaps for each soil type and physiographic unit within each. Plants generally are ranked as climax (natural) or invading. Climax species often are further classed as (*a*) those increasing (Fig. 43, page 123) under heavy grazing (generally the less palatable ones), and (*b*) those decreasing under heavy grazing (generally the more palatable ones).

It should be noted that, although this classification of species is *helpful*, plants may have different behavior in different situations and a particular species may be an *increaser* in one situation and a *decreaser* in another (2).

The Soil Conservation Service ranks vegetation in the Bighorn Basin of Wyoming as follows:

Climax decreasers	*Climax increasers*	*Invaders*
Bunch wheatgrass	Yarrow	All annuals
Idaho fescue	Snowberry	Gumweed
Geranium	Sagebrush	Snakeweed
Winterfat	Sandberg bluegrass	Foxtail barley
Indian ricegrass	Needlegrass	Horsebrush
Fourwing saltbush	Shadscale	Cactus
Big bluegrass	Rabbitbrush	Sandwort

Near San Angelo, Tex., the following ratings were assigned (4):

Climax decreasers	*Climax increasers*	*Invaders*
Big bluestem	Perennial threeawn	All annuals
Little bluestem	Tobosa	All woody invaders
Indian grass	Sand dropseed	Snakeweed
Side oats grama	Buffalo grass	Hairy tridens
White tridens	Curly mesquitegrass	Coneflower
Wild rye	Texas wintergrass	Red grama
Green sprangletop	Texas grama	Western ragweed
	Woody increasers	
	Forb increasers	

By listing the expected percentage of the climax composition contributed by each species and comparing to actual composition, it is possible to determine percentage of present floral composition that could be called climax. Obviously this would include all decreasing climax species, that portion of the increasing climax species not in excess of climax percentage, and no invaders.

Assume a range near San Angelo on very shallow upland soil has been examined and the present composition of the cover estimated, as shown in Column 2 of Table 27. Since side oats grama is a decreaser, any remaining plants are part of the original climax and would be entered in Column 3 as climax. Perennial threeawn is an increaser and the present 10 per

cent coverage is an increase of 5 per cent over that expected in climax cover. Therefore 5 per cent is entered in Column 3, since this portion is not considered abnormal. Annuals are not a part of the climax; hence none of the present 35 per cent annual cover is considered climax. Since the total of Column 3 is 30 per cent, the range can be said to support only 30 per cent of the normal climax cover.

TABLE 27. CALCULATING RANGE CONDITION FROM COMPOSITION OF THE PRESENT COVER IN PER CENT NEAR SAN ANGELO, TEX.
Data from Dyksterhuis (4)

Species or group	Contribution to climax composition,* per cent	Composition of present cover, per cent	Climax portion, per cent
Sideoats grama	100	10	10
Perennial threeawn	5	10	5
Texas grama	5	5	5
Forb increasers	10	5	5
Woody increasers	5	20	5
Hairy tridens	0	15	0
Annuals	0	35	0
		100	30

* Composition would not be expected to exceed this percentage under undisturbed climax conditions.

Present Soil Conservation Service practice is to designate ranges from 0 to 25 per cent of climax as poor condition, 25 to 50 per cent as fair condition, 50 to 75 per cent as good condition, and 75 to 100 per cent as excellent condition (4). The number of condition classes and the terms applied to each vary, but basically the method is widely applied in this manner.

The relationship between condition class and grazing capacity is determined from local stocking experience, experiment station results, and perhaps by actual determinations of differences in plant production under various situations. Such data are tabulated in a technician's guide according to average annual precipitation as shown in Table 28. Local site conditions, as soil depth and physiographic location, may further increase or decrease these grazing-capacity estimates.

Forest Service Method of Condition Analysis. Although composition of the flora compared with climax conditions is an important index to range condition, it is but one factor that might be considered. The U.S. Forest Service (11) does not consider species composition an adequate base for condition classification on mountain ranges.

It is obvious that a range in excellent condition could be expected to have vigorous growth, adequate reproduction, loose, friable topsoil with litter accumulation on the surface, and little erosion and runoff. A poor range will be occupied by plants low in vigor, density often will be low, soil may exhibit erosion pavement, plants will be hedged, and good plants are inhibited in reproduction. A good range manager will have a *concept* of excellent range, broad in application. This concept will involve many range characteristics, but all may be combined into a single classification.

TABLE 28. RELATIONSHIP BETWEEN RANGE-CONDITION CLASS AND GRAZING-CAPACITY ESTIMATE NEAR SAN ANGELO, TEX.
Data from Dyksterhuis (4)

Average annual precipitation, inches	Climax portion, per cent			
	100	75	50	25
	Animal unit months per acre			
14–18	0.6	0.45	0.3	0.15
19–24	0.8	0.6	0.4	0.2
25–29	1.0	0.75	0.5	0.25
30–34	1.2	0.9	0.6	0.3

The U.S. Forest Service has devised a complicated system, used with various modifications in almost every western region, for determining range condition by a series of rating points covering various range-condition factors. Ranges are finally classified into one of four (usually) classes according to the following scale based upon total rating points received:

Good condition..........	... Over 40 points total
Fair condition...........	... 30 to 40 points
Poor condition...........	... 15 to 29 points
Very poor condition......	... Less than 15 points

Soil Condition. First, points are allotted on the basis of soil factors. Since it is known that soil is a result of and dependent for its development upon the vegetation, close attention must be given to the soil. Important characteristics include the amount and distribution of litter, evidences of surface-soil removal, either through wind or water action, and the presence and nature of gullies. These soil factors are recorded and integrated with those which describe the vegetation in arriving at a range-condition rating.

The following soil-condition rating points have been proposed:

Class 1. *No soil loss or erosion;* no evidence of accelerated erosion, topsoil layer intact; well-dispersed accumulation of litter from past years' growth plus traces of older litter.................... Rating = 20 points

Class 2. *Soil movement slight and difficult to recognize;* small deposits of soil in form of fans or cones at end of small gullies or rills, or as accumulations back of plant crowns or behind litter; rill marks may be observed for a short period following storms; litter not well dispersed or no accumulation from past years' growth in evidence... Rating = 17 points

Class 3. *Soil movement or loss more noticeable;* topsoil loss evident; may be some pedestaled and hummocked plants; rill marks and alluvial deposits may be observed following storms; poorly dispersed litter; bare spots not adequately protected by litter and soil.. Rating = 10 points

Class 4. *Soil movement and loss readily recognizable;* topsoil remnants with vertical sides and exposed plant roots; plants raised above the general level of the surface soil by loss of soil around them, roots frequently exposed; terraces active; erosion pavement forming; recent alluvial deposits.................................. Rating = 7 points

Class 5. *Advanced erosion;* active gullies, well-defined and actively cutting into the soil mantle, steep side walls on larger gullies, may be recutting in the bottom; well-developed erosion pavement on gravelly soils; other indicators given under 4 above also in evidence. Rating = 0 points

Density as a Criterion of Range Condition. Schemes for condition classification ordinarily provide data on the vegetation under several categories. Most commonly the density, species composition, and vigor are observed. Utilization of the plants may be included, although this properly is not related to range condition.

Although density is frequently associated with range condition it is doubtful that exact definitive values may be found. Density may increase or decrease with range deterioration depending upon the species involved in the succession. Hanson (5) observed that density of grass types sometimes increased with deterioration because of the increase in forbs which produce a profusion of herbage. This behavior frequently has been noted in the prairie and mid-grass areas, where the secondary species are low-growing and turf-forming giving high density values but usually lowered herbage yields. Even climax supports low densities in poor habitats.

The Forest Service has suggested rating point allowances for density in percent of ground cover as follows:

Density	*Rating*	*Density*	*Rating*
0.50 plus	= 10 points	0.25	= 5 points
0.45	= 9 "	0.20	= 4 "
0.40	= 8 "	0.15	= 3 "
0.35	= 7 "	0.10	= 2 "
0.30	= 6 "	Less than 0.10	= 1 "

Vegetation Composition and Age. The Forest Service system also makes use of species composition in condition rating, although less specific reference to climax condition is made than under the Soil Conser-

vation Service system. Also age-class distribution of individual species is considered helpful in interpreting range conditions. Theoretically, seedlings and young plants should be present if any plant is to maintain itself in the stand, for deaths are constantly occurring among the older members. While age determination on shrubby plants may be made with some assurance by means of annual-ring counts, there exist no accurate guides to age of herbaceous species. Moreover, even when age can be approximated, the problem still remains of deciding whether reproduction is adequate for the maintenance of the species in question.

Rating points allowed for composition and age-class are as follows:

Class 1. Better perennial herbaceous forage plants abundant, age classes of 1-, 2-, 3-year, and older plants represented. Better forage plants available to livestock, growing in openings between shrubs........ Rating = 10 points

Class 2. Better perennial herbaceous-forage plants moderately abundant, age classes of 1-, 2-, 3-year, and older plants represented. Secondary plants moderately abundant to abundant. Better forage plants available to livestock, growing in openings between shrubs........ Rating = 7 points

Class 3. Better perennial-herbaceous-forage plants scarce, older plants only are found, may be a few seedlings present. Low value or unpalatable plants abundant. Better forage plants confined to protection of shrubs not commonly found in openings.............. Rating = 5 points

Class 4. Better perennial herbaceous-forage plants generally found as relics. Low value or noxious plants abundant, represented by age classes. Annuals may be moderately abundant to abundant. Better forage plants confined to protection of shrubs................ Rating = 1 point

Plant Vigor as a Criterion of Range Condition. Vigor of vegetation is important in connection with range-condition ratings. Indexes used are color, seed and rhizome production, size of plants, and annual growth produced. To the extent that vigor can be detected and defined, it is a useful tool, for decline in plant vigor precedes changes in composition. Unfortunately, however, determination of vigor is largely subjective, since no precise determinants exist.

Suggested point ratings for vigor are as follows:

Class 1. Palatable plants vigorous. Grasses robust with numerous leaves, seedstalks tall and numerous, leaves dark green. No hedged or high-lined browse. Forage plants reproducing.............. Rating = 10 points

Class 2. Palatable plants lacking in vigor. Forage grasses are shorter, fewer seedstalks. Seedlings may be present. Few forage plants of younger age classes represented. Less-palatable weeds and grasses are generally vigorous.................................. Rating = 7 points

Class 3. Palatable plants lacking in vigor. Grasses weak. Forage plants are not reproducing.................................. Rating = 5 points

Class 4. Palatable plants sickly and weak. Grasses may be pale, yellowish in color, seedstalks few and short, no seedlings. No reproduction of palatable plants, sod thinning........................ Rating = 1 point

Rating points earned from these four categories are totaled for each range or allotment and the over-all condition rating is determined from the scheme shown on page 182.

Influence of Site upon Range Condition. One of the factors that makes a universal scheme for classifying range lands difficult if not impossible is the fact that great differences within the same vegetation type occur on different sites. Short grass differs in density, species composition, and vigor, depending upon the soil factors. As a result the maximum production in a poor site may not be equal to subnormal production for a good one. In consequence of these variations, range appraisals are only accurate to the extent that these site variations are recognized by the appraiser. They prevent use of any one density or species composition as an index to a given range condition. This problem is recognized, and different levels of forage production or density are oftentimes used as an index to condition, even within the same forage type, because of this variation in potential (6).

To date no universally accepted basis for vegetation analysis has been developed for the determination of range condition. Although the principles are known, experience has not yet supplied adequate information upon the behavior of individual species in all the vegetation types and sites to provide entirely accurate measuring sticks.

Among other objections to condition classification is that it presupposes knowledge of climax or normal conditions. It is not always possible to determine the climax with reasonable assurance. There is also the question as to whether climax is the most productive or desirable condition. Perhaps it is an uneconomical goal.

This method, despite its faults, is rapidly becoming the most used basis for deciding upon stocking intensity in America. This attests to its general soundness and reliability compared with other methods.

RANGE-CONDITION TREND

Condition ratings, even though they are accurate, are of little usefulness without appraisals of range trend. A range in poor condition which is still deteriorating requires different treatment from a poor range which is in process of improving. Trend can be determined only by a further analysis of the range, including a number of the factors which are used for establishing condition. Among the most important are vigor and reproduction of both desirable and undesirable plant species.

Determining trend is highly important. Generally, stock reductions and wide-scale changes in management are unnecessary if condition trend is upward, although, by improved management, *rate* of range improvement may be increased. Poor range condition does not mean that

current grazing practices are wrong. Only trend of condition will reflect correctness of current grazing practice.

Trend is difficult to determine, and it usually is evident only after careful study, sometimes involving study plots and many years of observation.

However, the U.S. Forest Service has used a scoring system which might aid in such analyses. The following shows suggestions for both forage-condition- and soil-condition-trend analyses to be used when the range is in various condition classes:

TREND IN FORAGE CONDITIONS

	Circle pertinent item and balance:	
	Plus	Minus
Good (or excellent) condition		
Desirable or choice species reproducing the stand	2	
Utilization not excessive for stand in good condition	1	
Browse in healthy condition	1	
Death loss or breaking up of desirable plants noticeable		2
Secondary species invading		2
Utilization of desirable or choice species excessive		1
Browse hedged and dying		1
Fair condition		
Desirable or choice species invading bare spots and replacing undesirables or secondary species	2	
Utilization not excessive for stands in fair condition	1	
Browse recovering from past grazing damage	1	
Low-value species reproducing markedly		2
Utilization exceeds standards for fair condition		1
Browse hedged, dying, dead, and inferior species, if present, closely grazed		1
Poor condition		
Desirable or choice species invading bare spots and replacing other less desirable plants	2	
Utilization not excessive for stands in poor condition	1	
Browse recovering from past grazing damage	1	
Low-value species and annuals reproducing markedly		2
Utilization exceeds standards for poor condition		1
Browse hedged, dying, dead, and inferior species, if present, closely grazed		1
Very poor condition		
Secondary species definitely becoming established	2	
No utilization by livestock and game	1	

Trend in Soil Conditions

	Circle pertinent item and balance: Plus	Minus
Good (or excellent) condition		
Normal cover of litter is being replaced each year	3	
No visible accelerated erosion	2	
No trampling displacement occurring	1	
Rodent activity normal or below	1	
Litter is not accumulating		3
Plant cover breaking up and exposing small spots of bare soil		2
Trampling displacement occurring		1
Rodent activity increasing		1
Fair and poor condition		
Litter is building up and covering bare spots between grass clumps	2	
Gullies, if present, healing, with sides well covered with perennial grasses	2	
Rills and alluvial deposits being stabilized with perennial grasses	2	
Trampling displacement insignificant	1	
Pedestals of desirable species healing on sides	1	
Litter is not accumulating and soil surface is being exposed		2
Gullies not healing over with perennial grasses		2
Rills and alluvial deposits not being stabilized with perennial grasses		2
Trampling displacement noticeable		1
Pedestals of desirable species steep-sided		1
Very poor condition		
Secondary grass species, annual weeds and mosses are increasing and covering up bare soil surfaces	2	

The foregoing score card does not measure the *rate* of trend but is intended only to indicate the *direction* of change within the previously determined forage and soil-condition classes. An excess score in the plus column indicates upward trend, whereas an excess score in the minus column indicates downward trend. A close balance indicates there is no marked trend up or down.

The effect of condition and trend determinations upon utilization of the range would be highly variable, but the Forest Service has suggested that normal full use is possible only in the higher condition classes having static or upward trend. The lower condition classes and those with downward trend could receive conditional use only. Such use might involve special management such as light grazing and rotation.

The transition from condition and trend analysis to grazing-capacity estimate always is based upon experience with comparable ranges. If a class 2 sagebrush range known to yield 10 animal unit days per acre is in upward trend or static, then it is assumed that other class 2 sagebrush ranges of similar ecological nature will safely carry comparable numbers.

Nothing but ecological knowledge plus range-managing experience will suffice to determine a standard of utilization. The range manager must carry always in his mind a picture of correct grazing. Although various tools and procedures may aid in the application, nothing can replace knowledge and experience in appraising grazing capacity of range lands. No accurate method of grazing-capacity determination has yet been devised which does not rely upon experience founded upon comparable range of proved grazing capacity (19).

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CHAPTER 8

RELATIONSHIP OF NATIVE FAUNA TO RANGES AND RANGE USE

A factor complicating the management of grazing land is the relations ip of native animals to range use. All animals feed directly or indirectly upon vegetation, and domestic livestock must share with wild animals and insects. This competition is almost always present and, at times, attains major proportions. The destruction of plant life by Mormon crickets and denudation by prairie dogs are examples. When such burdens are added to a range already fully utilized by domestic stock, serious damage results.

There is need for additional data on the extent of these losses and on the means and effectiveness of control. At the same time, beneficial relationships must be considered; for, certainly, there are advantages from these animals in many instances.

Three classes of native animal are recognized upon the basis of their relationship to range management: (*a*) herbivorous animals entering into competition with range livestock for forage, but which have direct economic value, (*b*) animals which consume plant life but which have little or no direct economic value, and (*c*) animals which prey upon range livestock. In the first class, the problem is frequently one of drawing a balance between the values presented by the animal involved and the reduction in grazing available to livestock. With the second and third groups, the question is largely one of weighing the cost of control measures against the returns to be realized.

BIG-GAME ANIMALS

The several species of game animal are known to consume large quantities of forage, but exact amounts are unknown. Such determinations are complicated by incomplete knowledge of (*a*) numbers of animals involved, (*b*) their quantitative forage requirements, (*c*) their dietary habits compared with domestic stock, and (*d*) the extent to which they utilize the same areas as domestic stock. Knowledge of the diet of native animals is of especial importance since, to a considerable degree, they

may consume species not desired by domestic animals. Further, wild animals often forage on areas not grazed by domestic stock, such as steep, rocky slopes and densely timbered land. The effect is to minimize competition.

Of the big-game animals, deer, elk, and pronghorn antelope are most important to range lands. Deer present the greatest problem to the range manager because of their larger numbers and general distribution. Three species of deer are important: the mule deer (*Odocoileus hemionus*), the white-tailed deer (*O. virginianus*), and the black-tailed deer (*O. columbianus*). Though the mule deer is much the most important in the West, the white-tailed deer is found in large numbers in the Southwest and East, and the black-tailed in the Northwest and coastal states. Of the remaining herbivores, the moose, bighorn, mountain goat, and bison, none should be regarded as a serious competitor, except locally (Table 29).

Methods of Calculating Forage Requirements of Game. Theoretically, the forage demand of game animals may be calculated on the basis of body

TABLE 29. NUMBER OF BIG-GAME ANIMALS IN THE WESTERN RANGE STATES AS OF 1952

Data from U.S. Department of the Interior (62)

State	White-tailed deer	Mule deer	Black-tailed deer	Elk	Prong-horn	Bighorn (desert and Rocky Mountain)	Moun-tain goat
Arizona*	30,310	50,887	....	5,125	8,430	1,470	......
California	....	500,000	586,600	1,000	3,500	1,650	......
Colorado	....	292,000	....	51,307	11,000	5,500	35
Idaho	24,552	129,000	....	35,100	13,400	2,500	3,570
Montana	43,115	176,923	....	42,089	59,160	1,743	4,544
Nebraska	7,890	18,415	....	66	3,150	......	.....
Nevada	....	90,000	....	250	4,013	3,500	......
New Mexico	19,000	110,000	....	6,500	24,000	300	......
North Dakota	13,000	5,500	....	60	2,350	......	......
Oklahoma	20,000	....	....	....	25	......	......
Oregon	1,500	325,000	200,000	32,000	10,000	......	......
South Dakota	55,130	26,700	....	1,610	10,195	25	300
Texas	450,000	5,000	....	400	8,000	25	.....
Utah	....	350,000	....	5,000	1,700	......	......
Washington	50,000	120,000	170,000	30,000	150	......	5,000
Wyoming	10,733	105,707	....	35,169	97,483	1,749	......
Total†	725,230	2,305,132	956,600	245,676	256,556	18,462	13,449
Animal Unit equivalent†	76,180	317,511	93,236	10,366	21,577	2,622	1,552

* 1948 data.

† Grand total 4,521,105 animals; 514,044 animal units.

weights, although the view has been advanced that body surface area is a better index (21). The use of body weight assumes that the efficiency of all animals in making use of feeds is equal. Experiments with cattle and sheep indicate that this assumption is false (page 271), the digestibility of forage being affected especially by the proportion of concentrate and roughage involved (18). It is likely that wild animals, also, differ in efficiency.

Table 30 shows some comparative feed requirements of game and domestic stock. These, in the absence of more precise information, are

TABLE 30. FORAGE-CONSUMPTION EQUIVALENTS OF SOME IMPORTANT GAME ANIMALS AND LIVESTOCK

Based on Relation of Average Herd-run Weights at the End of the Summer Grazing Season

Data from Rasmussen et al. (40)

Kind of animal	Pronghorn	Domestic goat	Domestic sheep	White-tailed deer	Mountain goat	Mule deer	Bighorn	Elk	Moose	Bison	Cattle
Cattle	9.62	8.92	8.02	7.68	6.97	5.82	5.64	1.88	1.15	1.00	1.00
Bison	9.59	8.90	8.00	7.66	6.96	5.81	5.63	1.88	1.15	1.00	1.00
Moose	8.39	7.79	7.00	6.70	6.09	5.08	4.93	1.65	1.00	0.87	0.87
Elk	5.10	4.73	4.26	4.07	3.70	3.09	2.99	1.00	0.61	0.53	0.53
Bighorn	1.70	1.58	1.42	1.36	1.24	1.03	1.00	0.33	0.20	0.18	0.18
Mule deer	1.65	1.53	1.38	1.32	1.20	1.00	0.97	0.32	0.20	0.17	0.17
Mountain goat	1.38	1.28	1.15	1.10	1.00	0.83	0.81	0.27	0.16	0.14	0.14
White-tailed deer	1.25	1.16	1.05	1.00	0.90	0.76	0.74	0.25	0.15	0.13	0.13
Domestic sheep	1.20	1.11	1.00	0.96	0.87	0.73	0.70	0.21	0.14	0.12	0.12
Domestic goat	1.08	1.00	0.90	0.86	0.78	0.65	0.63	0.21	0.13	0.11	0.11
Pronghorn	1.00	0.93	0.83	0.80	0.73	0.61	0.59	0.20	0.12	0.10	0.10

based upon relative weight. Care must be exercised in applying such figures, for wild animals may be resident on seasonal ranges for an appreciably greater proportion of the year than are domestic stock; hence, on the basis of numbers alone, the ratios would not hold true. Furthermore, such conversions do not allow for differences in forage species consumed and areas grazed by the different kinds of animals (53).

Methods of Determining Foraging Habits of Game. Three methods are used in determining the foraging habits of game animals: (*a*) field observations, either of the time spent grazing upon different plant species or of the amount of forage removal estimated from the appearance of grazed plants, (*b*) stomach analyses, and (*c*) feeding of captive animals. Each of these has certain disadvantages. Field observations of the time spent upon specific plants are liable to error, first, because of the difficulty of determining which plant of two or more in close proximity is being consumed, and, second, because plants do not yield identical amounts of

forage to a given grazing effort. It may require twice as long to secure an equal volume from bitterbrush (*Purshia*) as from a herbaceous plant such as geranium (*Geranium*). Estimates based upon examination of grazed ranges are more dependable; but it is seldom possible to find areas grazed by a single animal species; and there are limits to the accuracy with which an estimator can reduce his observations to volume consumption.

Stomach analyses, also, are subject to certain limitations. Usually, it is impossible to secure stomach samples adequate to give statistically reliable results. Further, there is a definite and limiting source of error, for certain plants seem to be broken down more rapidly than others when taken into the digestive tract. Succulent green material passes through more rapidly than dry or woody material. Deer stomachs taken when both green and dry forage are being eaten may show a disproportionately high amount of the dry feed. However, stomach analyses may yield reliable qualitative data.

Feeding captive animals has proved fairly successful, but it is costly and necessitates great effort. Results, once secured, may be of limited application, since they apply only to an area possessing vegetation in similar proportions to the forage offered to the animal. The different species of forage clipped and presented to animals may not retain their desirability equally. Nevertheless, certain information can be secured in this way only. When related to weight changes of the animals, this offers an accurate means of studying maintenance requirements of game.

Foraging Habits of Elk. Elk (*Cervus canadensis*) are essentially grass eaters, especially during the summer months and perhaps by preference during the winter also (4, 32). Other plants are grazed, however, during all seasons, browse forming a large part of the diet during the winter. In Montana (Table 31), grass was found to make up over 56 percent of

TABLE 31. FORAGING HABITS OF ELK IN MONTANA, BY CLASS OF PLANTS
Data from DeNio (12)

Forage class	Number of species present in diet	Volume composition of diet, per cent
Conifer	11	11.75
Shrub	31	15.46
Grasslike	4	8.39
Grass	18	56.58
Forb	16	2.35
Moss and lichen	3	5.25

the diet (12) and, when available, as much as 85 per cent (50). In Arizona, where snow does not prevent its being reached during the winter, grass is believed to be even more important (42).

Data shown in Table 32 indicate that the preference of elk is definitely toward grass, but also that both forbs and shrubs are important. It would seem that the general conception that elk are almost entirely grass eaters is not well founded. When feed is limited by deep snows, availability

TABLE 32. COMPARISON OF UTILIZATION OF THE MAJOR CLASSES OF FORAGE BY ELK IN YELLOWSTONE PARK
Data from Rush (43)

Forage class	Number of species grazed	Average use factor, per cent
Grass	21	67
Forb	8	47
Browse	6	30

becomes the criterion of use. In such instances, elk graze heavily upon browse; but when available, dried forbs and grasses are used. No other native herbivore is so versatile in feeding habits. For this reason, elk may compete to advantage with all other grazing animals. Actually, their diet is similar to that of domestic stock, particularly during the summer. Naturally, competition between the two is considerable. Because of their diverse dietary habits, their size, and their tendency to group together, elk may do great damage to the range (Fig. 70).

FIG. 70. The Gros Ventre elk range above Jackson Hole, Wyo., where concentrations of elk, especially on south-facing slopes, are ruining the game range as well as creating serious watershed and erosion problems. Livestock do not use this range.

Foraging Habits of Deer. Considerable work has been devoted to discovering the forage preferences of deer. These generally have revealed that forbs and browse are the most important. During the early period of plant growth, forbs may rank first in the diet. Since on most western areas, except at high elevations, forbs remain green and succulent for but a short period, they are early replaced in the diet by browse species, which remain succulent after herbaceous growth has dried. Throughout the winter months, where a snow cover exists, browse plants form nearly the entire forage. Figure 71 illustrates the seasonal change from herbaceous plants to browse.

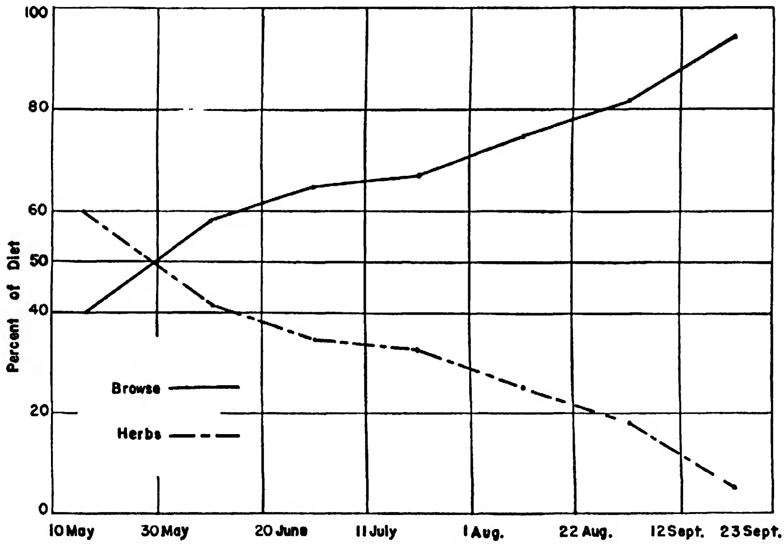

FIG. 71. Summer diet of mule deer in per cent showing relative importance of browse and herbaceous plants at various seasons.

Grass, except in the absence of other desirable forage, probably does not enter strongly into the diet of the deer. Experience gained feeding captive animals reveals that no grass species is eaten in the presence of a choice of other forage (49). Similarly, analyses of stomachs suggests that deer on the Kaibab National Forest secured less than 3 per cent of their diet from grass, although these results may reflect shortage of grass as well as preference (26). Where the ground is bare of snow, and green grass is available on heavily stocked winter ranges, it is utilized. For a brief period in early spring, it may become of considerable importance. As other green herbage becomes available, grass is forsaken. This brief period of use does not injure grass greatly, for on such heavily used ranges dense stands of grass and other herbs may develop while the brush declines.

Dasman found considerable use of grass in California; but the only readily acceptable browse, bitterbrush, constituted only 6 per cent of the vegetation (11).

Occasionally, artificially seeded ranges, and also farm fields, are subjected to heavy use by deer. Seeded ranges sometimes offer green herbage when that in the surrounding areas is dry. Often, too, some of the exotic grass species appear to be more attractive than native grasses, Russian wild rye (*Elymus junceus*), *Hordeum bulbosum*, and tall oatgrass (*Arrhenatherus elatius*) being sought (38).

Foraging Habits of Pronghorn Antelope. Pronghorns were once limited in numbers on the western range but have in recent years increased tremendously. Since they were found on open plains and mesas, it was early assumed that they were grass-eating animals. Investigations have shown this to be false, grass being of minor importance. Throughout the northern parts of the antelope range, browse has been found to make up about two-thirds of the diet (Table 33).

TABLE 33. DIET OF THE PRONGHORN IN SOUTHERN AND NORTHERN PARTS OF ITS RANGE, PER CENT (7, 13)

Forage class	Southern	Northern
Browse	30	74
Forb	67	22
Grass and miscellaneous	3	4

Moreover, most of the browse plants were those low in palatability to livestock, sagebrush (*Artemisia*) often being the most important single genus (13). In the southern plains, forbs were found to be of greater importance than browse. Many of the species most heavily used were not important as livestock forage (7).

Competition for Forage between Livestock and Game. The degree of competition between livestock and game cannot be precisely stated. Variations exist in different regions and vegetation types and because of topography and range conditions. Game animals make greater use of a range than will livestock, because of their willingness to accept, if not preference for, the more inaccessible areas. In one instance, deer were found to cover 92 per cent of a range area, while cattle covered but 52 per cent. Similarly, deer use appeared to be about 25 times as heavy in oak types as compared to sagebrush types. Conversely, cattle use was 7 times as heavy in sagebrush types as in oak (23). Similar instances of partial separation of deer and sheep have been noted (51). Under western mountain-range conditions, it has been estimated that deer obtain only about 50 per cent of their forage from areas that are regularly used by

cattle and about 75 per cent from areas regularly used by sheep (53). On nearly level and open range, these figures would approach 100 per cent. For these reasons, total numbers alone cannot indicate degree of competition.

Certainly, competition might be reduced if range lands were to be stocked according to their suitability for use. Many areas where adverse conditions result in poor use by livestock could be devoted entirely to game production. If ranges were stocked with livestock on a more realistic basis, competition would be lessened.

FIG. 72. Heavy concentrations of deer during the winter months resulting from a too small winter range are common in parts of the West. (*Courtesy of Lee Kay, Utah Fish and Game Commission.*)

The vegetation present may modify overlap in forage consumption. Where ranges are in good condition and there is a variety of species, generally less similarity will exist in diet. Studies conducted in northern Utah show that *Helianthella uniflora*, *Senecio serra*, and *Lupinus* are all important sheep forages, but only the latter is taken by mule deer and this only in moderate amounts. *Geranium fremontii* ranks high in the diet of deer and provides little if any forage for sheep. Were heavy range use to eliminate any of these preferred plants from a range, lack of choice would force both to subsist upon the same species.

The contrary may be true, however. Where overgrazing alters the climax vegetation, often secondary species highly acceptable to game

animals replace the preferred livestock forages. Buechner (7) has observed this in Texas on cattle-pronghorn range, and Leopold (27) believes it to have been a factor in the irruption of deer herds throughout the West. Since, however, the object of range management is to maintain a highly productive range, competition should be appraised upon the basis of proper grazing levels.

Range Damage Due to Winter Concentrations of Game. The magnitude of the big-game problem is not adequately indicated by the total numbers of animals. Since much of the natural winter range of game has been cultivated and settled upon until it is no longer available, game are forced to concentrate on an abnormally small area (Fig. 72). The result is local intensification of grazing such as to be ruinous not only to the range but sometimes to the animals themselves. Such concentrations may result in less than 1 acre of range per animal. Intense overuse frequently results (Fig. 73). This concentration may continue in the spring until higher ranges are quite free of snow. As a result, heavy use prevails during the period when grasses are beginning growth on the lower ranges and when the soil is wet from thawing snow and spring rain. Elk especially may cause considerable damage (30).

FIG. 73. Extensive damage may result from overgrazing on ranges where game animals are concentrated during the winter, especially to tall growing plants, such as this Utah juniper (*Juniperus utahensis*), which protrude above the deep snows.

Summer-range damage usually is less serious. The disproportionate summer and winter range available to game enables the summer range, in most cases, to carry easily the animals that can survive the winter. Exceptions, however, exist, and sometimes summer ranges show the familiar *high line* of excessive browsing by game animals (Figs. 57, 58, 74).

Economic and Social Problems Associated with Game-livestock Competition. One of the factors that makes difficult the problem of game management is the peculiar status of these animals. Rooted in the early English laws is the concept of game animals being the property of the Crown rather than of the landowner. Resident game animals in America are still managed by the states, and because much of the range occupied by the animals is federally or privately owned, conflict is inevitable.

Sportsmen are in the majority, and their interest usually is in increased game; therefore, stockmen and landowners face a difficult problem. Whereas stockmen often are unreasonable in their demands for exclusive use of federal lands, some sportsmen add to this problem by blind opposition to anything resembling control over the game numbers. Virtually any management program, involving, as it almost inevitably must, reduced numbers, is loudly opposed by the many sportsmen (54).

The effect of competition from game sometimes is of great importance because of the resultant reduced grazing capacity for domestic stock. There is justification, over much of the West, for concern on the part of

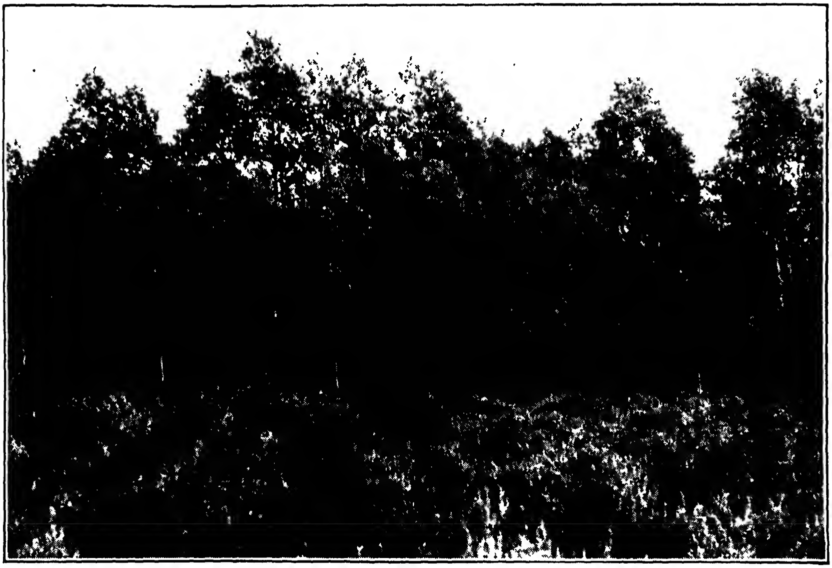

FIG. 74. Excessive deer grazing on summer range often can be detected by a highline where deer have trimmed all available foliage as on these aspen trees.

landowners over excessively high deer populations. Under present laws, there is little provision made whereby landowners can be remunerated for furnishing forage to publicly owned game, and it is natural that they should resent excessive numbers. Conversely, on public land, there may be little justification for reducing game numbers below the carrying capacity of the game range. Many people derive enjoyment from game on the public lands. These lands are owned by the people, and thus there is reason for questioning the restriction of game to allow the relatively few stockmen greater privileges.

Competition of livestock against game animals is as serious as is the reverse. These conflicting demands could best be settled by intelligent compromise. Dual use of public ranges by domestic and wild animals is

entirely possible and desirable. Livestock could not be eliminated from the public lands without serious economic upsets involving not only livestock owners but also the general public (54). Likewise, the public has every right to demand range for game animals, but only within reasonable limits. Careful studies of range conditions, game numbers, public-hunting demands, livestock numbers, and livestock-production economy are greatly needed. Such studies would point the way to a thoroughly compatible dual usage, according to which livestock men graze their animals part of the year upon public lands, and publicly owned game graze part of the year upon private lands. Only when landowners, game managers, stockmen, and sportsmen can look upon land as a public heritage that must be conserved and used to the greatest good of humanity, can game-livestock conflicts be settled. Only then can game management be based upon forage supply and economic needs—the only logical foundations for determining numbers.

SMALL MAMMALS

Range land is almost all occupied by small mammals. The importance of these is probably greater than commonly believed, especially in the case of rodents. Many of these small animals consume much the same vegetation as domestic animals, and they do amazing damage to the range during periods in which large populations occur. A classical example of rodent damage is that of the common rabbit in Australia and New Zealand. These countries have no range problem more serious, and the animals have necessitated extensive rabbitproof fencing and costly control campaigns. Throughout western America, the jack rabbit and the ground squirrel are residents of the range and consume large quantities of forage. In the Southwest and the plains states, the prairie dog and the kangaroo rat reach numbers that enable them to do great damage. Studies in the Southwest show that consumption of forage by rodents amounted to 28.7 per cent of all vegetation present and 38.8 per cent of the most valuable grasses (65). Students wishing to know of methods of determining rodent pressure on the range should refer to the discussion of the problem by Taylor (57).

Rabbits. Rabbits are abundant throughout the West, the jack rabbit (*Lepus* spp.) being the most important. Several species are present on the range, differing in size but having similar feeding habits. Most important are the black-tailed and white-tailed jack rabbits. The former are most common in the southern and intermountain regions, and the latter are most numerous in the plains. The black-tailed jack rabbits are more damaging to the range, for they more frequently attain high populations. They have become so numerous that control campaigns, in which they

are driven into temporary corrals and killed, are not uncommon. Several thousand may be removed in this manner in a single day in parts of the West.

Despite the importance of this group to the grazier, little is known as to numbers and their effect in removing forage from the range. Two species have been studied in the Southwest (3), the black-tailed jack rabbit (*Lepus californicus*) and the antelope jack rabbit (*Lepus alleni*). These tests showed that the forage requirements of the two species were such that 62 black-tailed and 48 antelope jacks were the equivalent of 1 cow. Because of differences in dietary habits, 260 black-tailed and 164 antelope jacks would be required to remove range forage sufficient to feed a cow.

Prairie Dogs. The prairie dog (*Cynomys* spp.) is one of the most injurious rodents of the Southwest and the plains region. These animals assemble in areas called towns, where populations become very high; thus, the removal of vegetation in its entirety from the vicinity is common.

Prairie dogs compete directly with livestock for forage, especially cattle. In studies in northern Arizona (59), the kind of animal permitted to graze was varied on fenced plots. Certain plots were available to both rodents and cattle, others were restricted to either rodents or cattle, and still other plots were protected. Of a total production of 2,252 lb. per acre of the three most prominent forage grasses, western wheatgrass, sand dropseed, and blue grama, 1,819 lb. was consumed by prairie dogs. This represents a reduction in forage of 80 per cent. Heavy and continued use of sand dropseed resulted in almost total elimination from areas available to the prairie dogs. Food-habit studies show that prairie dogs eat nothing not eaten by cattle and that the two eat grasses in the same order of preference.

Prairie dog stomachs, mostly from Montana, Wyoming, Colorado, and Arizona, showed that the black-tailed prairie dog (*Cynomys ludovicianus*) and the Gunnison prairie dog (*Cynomys gunnisoni*) consumed largely grasses, though the white-tailed prairie dog (*Cynomys leucurus*) resorted

TABLE 34. COMPOSITION OF THE DIET OF VARIOUS SPECIES OF PRAIRIE DOG
Data from Kelso (24)

Animal species	Grass family, per cent	Goosefoot family, per cent	Miscellaneous plant groups, per cent	Animal material, per cent
Black-tailed prairie dog	61.55	12.73	24.32	1.40
White-tailed prairie dog	28.09	50.63	20.42	0.86
Gunnison prairie dog	47.26	13.80	33.61	5.33

mostly to the goosefoot family (Table 34). Plants valuable as stock forage constituted over 78 per cent of the food of these three species, valueless plants being only 19 per cent. Only 45 per cent of the diet was grass (24).

Fortunately, extensive poisoning campaigns, which are notably successful against prairie dogs, have all but eliminated them over much of the western range.

Kangaroo Rats. Throughout the Southwest the kangaroo rat (*Dipodomys* spp.) occurs in great numbers. These animals live largely upon seeds which they collect in cheek pouches and store in burrows (Table 35).

TABLE 35. MAJOR PLANT TYPES RECOVERED IN MERRIAM KANGAROO RAT POUCHES

Data from Reynolds (41)

Type of plant	Percentage of occurrence in pouches	Percentage of total vegetation
Grasses:		
Perennial	33	5
Annual	69	35
Forbs:		
Perennial	34	15
Annual	34	39
Woody shrubs	13	5
Cacti	13	0.5

Frequently, kangaroo rats congregate, and plants in the vicinity of a community are denuded of seeds (45). Examination of 21 burrows in the Southwest showed an average of 3.7 lb. of material stored in each. With a population estimated at 1,280 rats per section, this would amount to 2.37 tons for each 640 acres (64).

However, not all of this stored material is lost. When seed is abundant, more may be stored than is used, and the surplus may germinate, resulting in an increase in the quantity of the preferred food items (41). It was concluded that only in times of low seed production would the grasses be harmed. Rats did appear, however, to be a factor in the increase of mesquite and cholla cactus.

Ground Squirrels. Ground squirrels (*Citellus* spp.) are widely distributed, one species or another occurring throughout the West. With heavy reduction of the coyote, reduction in preying birds, and favorable influences resulting from cultivation, numbers have increased markedly. Numerous examples have been witnessed in which rodent increase coincided with breaking the original sod and later abandonment of such areas. Populations in fields are, in general, higher than those on range land, but

high populations and extensive damage frequently are observed on western grazing land (Table 36).

Shaw (46) estimates, for Columbian ground squirrels, that the material consumed daily equals 17.2 per cent of their weight. He calculated that 385 Columbian ground squirrels are equivalent to 1 cow, and 96 are equivalent to 1 sheep. Grinnell and Dixon (20) estimated that the forage eaten on a densely populated section of land by the Oregon ground squirrel was sufficient to feed 90 steers throughout the growing season, 750 squirrels consuming as much as 1 steer.

TABLE 36. COUNT OF GROUND SQUIRRELS (*Citellus armatus*) ON TWO SAMPLE AREAS IN NORTHERN UTAH AFTER USE OF POISON GRAIN

Plot number	Area, acres	Kill after 1 day		Kill after 2 days	
		Total	Per acre	Total	Per acre
1	2.8	176	62.8	240	85.7
2	3.6	243	67.5	319	88.7

Consumption may not fully express the loss in herbage. Ground squirrels confined in pens at the rate of 12 per acre were observed to reduce the herbage crop by 35 per cent, much more than their forage consumption would indicate (17).

Pocket Gophers. Pocket gophers (*Thomomys* spp.) are common on open ranges at high altitudes and are known to have voracious appetites (44). Their food is largely made up of the fleshy parts of plants found underground, but they also collect herbage in the vicinities of the tunnel openings (1). To a considerable extent, the major items of food are plants which are not the more desirable forage plants, being either low in palatability to livestock or plants which increase under heavy grazing. The effect of these animals on range is not firmly established by existing data. One study indicated the possibility that gophers hold depleted mountain meadows in poor condition (29). In another instance no harmful effect was attributed to gopher activity, although there appeared to be changes in vegetation which could be attributed to the food habits of the animals (15). Probably normal populations of gophers could be expected not to interfere with grazing values on ranges in satisfactory condition.

Rodent-control Methods. The most successful method for control of rodents is the use of poison baits. With the exception of pocket gophers, grain is the medium. In most cases, strychnine is the poison principle, although thallium has been successful. Poisoning is accomplished by placing a small amount of grain near the burrows. The amount that can

be held between the thumb and forefinger is ordinarily sufficient. This should be scattered over the ground surface rather than placed in a pile, for thus it will not be taken by livestock. All holes should be poisoned, even though they do not appear occupied. A few rodents, such as the Gunnison and Zuni prairie dogs, require prebaiting or scattering of unpoisoned grain previous to actual poisoning (28).

Rabbits usually are poisoned during the winter in areas having winter snow, alfalfa hay being used. At this time, forage is scarce, and the animals travel a distance of 1 mile or more to reach feed. The practicality of rabbit poisoning, however, is subject to considerable question. When jack rabbits are yarded up into winter concentration areas, drives are effective, thousands being taken during a single day.

Pocket gophers are poisoned by placing baits such as carrots in the burrows. These should be long enough to require the animal to cut the piece before it can be placed in the cheek pouch; otherwise, poisoning may not be effective. Most such animals are subject to diseases which occur in excess populations. Actually, reducing populations by poison, unless done thoroughly, may merely reduce population to a point that disease is not encouraged, and harm rather than good may result.

INVERTEBRATE ANIMALS

Frequently, invertebrates become so numerous that serious grazing-capacity loss is entailed, losses from this source often being more important than those from rodents and big-game animals (10). Insects commonly attack range plants in the greatest numbers when drought conditions prevail, and hence the effects of their activity are severe.

Probably the most damaging invertebrates on western ranges are grasshoppers and crickets. Grasshoppers are regarded by many as second only to drought in destructiveness to range land (63), many instances being known in which these insects have denuded land of virtually all forage. Because of the grasshopper's small size, ranchers do not always appreciate the extent of their damage. It has been estimated that in Montana the value of range forage lost during the years 1934 to 1936 amounted to $1,750,000 (55). In 1937, it was estimated that losses from grasshoppers in 24 states amounted to nearly $66,000,000 (63).

Dietary Habits of Grasshoppers. Evaluation of forage consumption by insects is complicated by several factors, populations as well as feeding habits being important. Not all material consumed can be regarded as valuable forage. Few of the species of grasshoppers present in Arizona are damaging (5).

Varied consumption by different species of grasshoppers has been noted in Montana, certain species causing considerable forage loss even with

moderate population (2). When populations become high, literally all vegetation may be taken.

Morton (31) in Montana estimated that the material destroyed by grasshoppers from 3 acres during 1 month was sufficient to keep a cow for 1 month. This loss was based upon a population of 25 grasshoppers per square meter and was attributable in part to the great amount of material that was cut but not actually consumed. Table 37 shows the forage loss at several stations during the summer of 1936 to average 67.0 per cent of total production.

TABLE 37. FORAGE LOSS FROM GRASSHOPPERS ON A RANGE IN MONTANA, 1936
Data from Morton (31)

Station	Loss of grass, per cent	Loss of all forage, per cent
1	100.0	97.3
2	11.1	20.8
3	79.0	80.2
4	58.5	49.8
5	68.8	76.1
6	88.1	88.4
7	92.8	94.0
8	91.4	87.9
9	70.0	66.6
10	10.6	9.3
Average......	67.0	67.0

In other areas, forage destroyed has been even more severe. Hanson made observations in North Dakota and found that, by the end of July, the average forage loss of six of the choice species amounted to 89 per cent of total production. Based upon 37 species, which included many plants of moderate to low forage value, the destruction of material was 43 per cent of the forage produced (31).

Mormon Crickets. Although less common than grasshoppers, Mormon crickets, because of their gregarious habits, may locally consume great amounts of herbage. Almost any plant may be taken by them, but the preferred plants are largely those which also rank high as forage for livestock. Studies have been made which showed that where 45 per cent of the herbage was removed, this might result in 74 per cent and 98 per cent reduction of the forage available for cattle and sheep, respectively (56).

Forage Loss from Other Invertebrates. Considerable loss of forage may be entailed at times as a result of infestation by insects. Data secured in

northern Utah during the summer of 1938 showed that consumption of snowberry (*Symphoricarpos*) by caterpillars amounted to approximately 10 per cent of the total forage available to cattle and about 24 per cent of that available to sheep. Estimates from pastures in New York, based upon careful census and observations of feeding habits of insects, led to the conclusion that, under certain conditions, more grasses and other forage were consumed by insects than by cattle (66).

Red harvester ants (*Pogonomyrmex* spp.) denude parts of many range areas. It is estimated that as much as 6 per cent of a range may be left bare, and that seed is collected from as much as 30 per cent of the range (25). This seed-collecting habit may be an important source of loss on artificially seeded areas.

Ranges in southern Idaho have been decimated of shadscale (*Atriplex confertifolia*) presumably by a species of snout moth (22). In this case the plants are killed by the insect, hence the damage is more serious than is inflicted by foliage consumption. Doubtless many other insects of importance have escaped notice or have been supposed to be of minor influence.

BENEFICIAL EFFECTS FROM WILD LIFE

Not all the influences of native animals are detrimental to livestock production. Doubtless the activities of rodents in burrowing may counteract soil compaction, favoring plant establishment and water infiltration (6, 14, 19, 58). Moth larvae have been observed to feed upon and thus reduce the amount of prickly pear cactus, which invades and reduces grazing values on the plains (8). The beetle *Chrysolina* was introduced to America because it successfully holds in check the poison weed Saint Johnswort, upon which it feeds.

CONTROL OF COMPETITIVE ANIMALS BY PROPER RANGE MANAGEMENT

Management of range land offers a means whereby competition from rodents and insects may be kept within reasonable limits. Heavy grazing, especially when accompanied by reduced grass and increased weedy species, causes increased rodent and insect numbers. Thus, these animals may be the result of, as well as the cause of, overuse of ranges. In Arizona and New Mexico, jack rabbits frequented heavily grazed areas, being more numerous than on well-grassed range (34, 60). Abandoned farm lands that have reverted to weeds attract large numbers of rabbits, the greatest populations being found on the most sparsely vegetated lands (36). Similar observations have been made concerning prairie dogs (35).

Canadian workers (61) found direct correlation between range depletion and grasshopper outbreaks. Where numbers of livestock were controlled, grasshoppers did not injure range grasses, the grasshopper damage being

a secondary or subsidiary factor to overgrazing. Control of grasshoppers on range land can best be accomplished by judicious grazing. Studies of insect populations in Oklahoma (60) showed 782,000 per acre on heavily grazed range and only 186,000 on moderately grazed range (Table 38). This increase of invertebrate forms of animal life accompanying misuse of land also has been noted in the case of the beet leaf hopper (*Eutettix tenellus*), misused lands providing more favorable conditions for the multiplication of this crop-disease-carrying pest than virgin lands (9, 36, 37).

TABLE 38. POPULATION OF INVERTEBRATE ANIMALS, THOUSANDS PER ACRE, CLASSIFIED INTO ORDERS UNDER TWO RANGE CONDITIONS
Data from Taylor, Vorhies, and Lister (60)

Range condition	Coleoptera	Diptera	Hemiptera	Homoptera	Hymenoptera	Orthoptera	Total
Overgrazed..........	118	30	100	214	140	180	782
Normal.............	50	28	8	52	28	20	186

Although it would be incorrect to assume that all competition from undesirable animal forms is due to range misuse, there is sufficient weight of evidence to suggest that much of the difficulty is attributable to this cause. One may properly inquire, therefore, whether control of undesirable forms might be sought by restoration of a proper balance between forage and livestock, rather than by costly and often not too successful control programs.

LIVESTOCK PREDATORS

Loss of livestock, especially sheep, on western ranges from predators is a major problem and has provided an incentive to widespread predator-control programs. Government trappers operate in all western states, and each year they take thousands of animals by trapping or with poisons. In addition, widespread private trapping and hunting, together with livestock-association efforts, account for many predators. Bounties by many states, counties, and livestock associations stimulate private hunting and trapping.

The Coyote. By far the most important predator is the coyote (*Canis* spp.), who has become almost a symbol of the open range (Fig. 75). These wolflike creatures prey upon sheep and, occasionally, young calves.

Although considerable damage is done to livestock by the coyote, it should not be supposed that domestic animals constitute its major source of food. Coyote stomachs taken from nearly all states of the West have shown that other items make up a greater percentage than do domestic stock (Table 39).

Early efforts at coyote control enjoyed but partial success. In fact, there was some indication that coyote numbers increased in spite of extensive control campaigns. The deadly new poison 1080 has given remarkable results as has the cyanide bomb, and coyote numbers are much reduced all over the West.

Other Predators. The wolf, a close relative of the coyote, has been subjected to hunting and trapping until it is a problem in the United States only in a few small areas. Being larger, the wolf is a much more

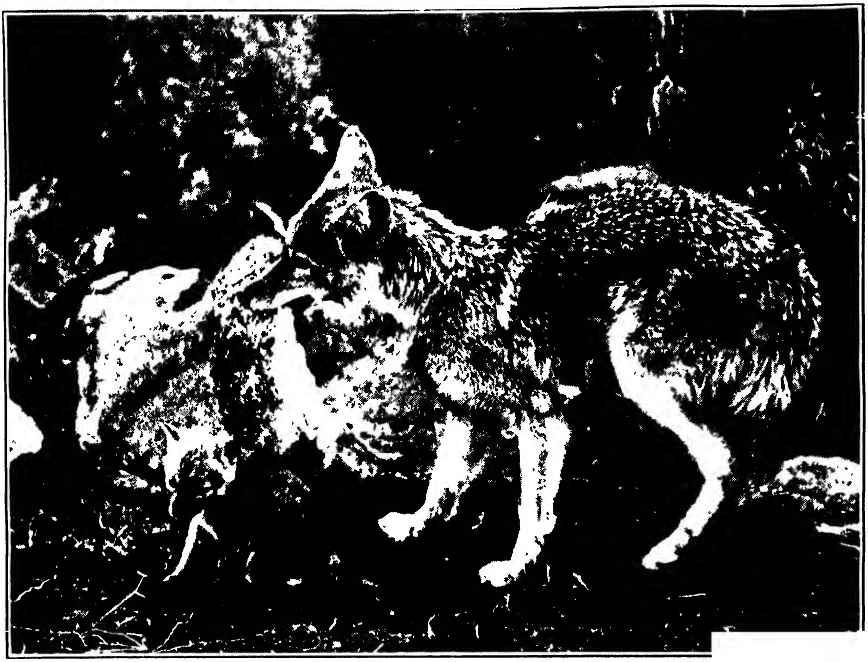

FIG. 75. The coyote, a symbol of the western range. (*Photographed at Kim, Colo., by E. R. Kalmbach, U.S. Fish and Wildlife Service.*)

successful predator and formerly was a major enemy of the stockman, surpassed by no other animal.

The cougar, puma, or mountain lion (*Felis* spp.) is one of the most successful predators, though its activities are concentrated upon wild animals, especially deer. An individual is believed to kill from 10 to 20 deer per month in many areas. It is especially destructive in winter, when snows prohibit easy movement of its prey. Horses, cattle, and sheep all are occasionally its prey; but though individuals do considerable damage under certain conditions, the cougar is not considered by most stockmen as a great danger. Most of its bad reputation comes from the occasional but sensational killing of 20 to 30 head at one time.

The bear, especially the grizzly (*Ursus* spp.), is regarded as a range predator of considerable importance, though losses are less than usually believed. The grizzly, especially certain individuals, is a born killer and was greatly feared in the early days. The black bear (*Euarctos* spp.) is a predator upon livestock under certain conditions. Individual bears, especially old animals that have lost their ability to rustle, attack sheep

TABLE 39. PERCENTAGES BY VOLUME OF VARIOUS CLASSES OF FOOD FOUND IN COYOTE STOMACHS
Data from Sperry (52) *and Ferril et al.* (16)

Class of food	Volume, per cent	
	Sperry	Ferril
Animal food:		
Mammals:		
Rabbits	32.0	22.3
Livestock (carrion)*	26.0	11.1
Rodents	17.5	26.5
Domestic livestock:		
Sheep and goat	13.0	7.2
Calf-colt-pig	1.0	
Deer	3.5	13.8
Miscellaneous	1.0	
Birds	3.0	4.6
Poultry	1.0	
Game birds	1.0	
Nongame birds	1.0	
Reptiles	Trace	
Amphibians	Trace	
Fishes	Trace	
Invertebrates	1.0	
Vegetable food	2.0	4.0
Cultivated fruit	0.5	
Wild fruit	1.0	
Other vegetable matter	0.5	

* Flesh of mature cows and horses as well as old weathered animal remains. This material was believed not to have been killed by the animal that consumed it.

and, occasionally, calves. The grizzly bears virtually have been eliminated from western United States, though Canada and Alaska support large numbers. The black bears have been eliminated from much of their former range; only in a few areas are they numerous.

The bobcat (*Lynx* spp.) has been known to prey upon sheep, particularly lambs; but it is seldom a danger to range stock under ordinary conditions. Serious losses have been inflicted, however, in local areas.

Coactions of Competition and Predator Control. A striking ecological relationship is exemplified in the control of livestock predators and the increased competition for range forage by wild grazers. Despite the stock losses they inflict, predators may prove to be desirable in that they do great benefit through control of rabbits, rodents, and insects. These constitute a major part of the diet of the coyote. Removal of predators such as the bear and cougar probably has done much to increase the numbers and hence competition from deer and elk. Since other wild animals are the natural prey of predators, the removal of the predator will naturally increase the numbers of the former. Conversely, poisoning of rodents and hunting of big game may increase the losses of livestock from predators. It seems likely that even destruction of insects such as crickets and grasshoppers may affect predation upon livestock.

Indiscriminate poisoning and shooting of wild life is capable of seriously upsetting the balance that nature attempts to establish between plants and animals and between the hunted and the hunter. The complexity of these interrelationships is such as to make very unwise widespread control activity that has not been carefully considered (47).

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CHAPTER 9

RELATIONSHIP OF GRAZING TO TIMBER, WATER PRODUCTION, AND SOIL CONSERVATION

Many land products and responses are closely related to range management. Game problems already have been discussed. In addition, many ranges are either current or potential sources of timber, management of which sometimes takes precedence over livestock production. Because of the interrelationships between timber management and range management, the western land manager must understand both.

Virtually all range land can be said to have significance as a watershed. Although many arid ranges are not sources of living streams, they may be the source of floodwater and sediment from surface flow following unusually heavy storms, thus affecting the quantity and the quality of water present in streams. Other ranges are the headwaters of western rivers. On these ranges, the source of the West's valuable water supplies, water production is of paramount importance. Grazing becomes strictly secondary.

Conservation of the soil is related to water production. Generally good range management is good watershed management and, if the watershed is grazed properly, problems of erosion and runoff are at a minimum. Floods cannot be eliminated by ordinary means of land management, but there can be no doubt that mismanagement of land accelerates flooding and creates problems even in years of relatively normal precipitation.

TIMBER AND RANGE LIVESTOCK PRODUCTION

Because many of the lands used for grazing in the West are also timber-producing areas, correlation of these two land uses is important to the land manager. A similar need for correlation of these uses exists in the southeastern United States (Fig. 38, page 88) and, to a lesser extent, on wood lots of the Northeast. Since neither timber production nor range forage production can be maximized on forested ranges without some impact upon the other use, the interrelationships of the two are important.

Effect of Grazing upon Tree Establishment and Growth. Young trees, since they are within reach of animals, often suffer from defoliation and

removal of shoots and buds. The possible severity of damage from this cause is suggested in the occasional use of goats to clear fields of brush and tree sprouts. While proper grazing from other kinds of livestock is less severe, damage is sufficiently common to require consideration in grazing management plans on timbered areas.

Defoliation is not the only manner in which damage to trees occurs. The disturbance of the soil through trampling has a marked effect upon seedling establishment. Once established, seedlings may be uprooted, and mechanical injury may be serious. Plants injured by being trampled may suffer retarded growth and ultimately succumb to disease attack as a result of the injury. These effects are especially severe where animals congregate, and may result in complete failure of regeneration in the more frequented areas.

Limited damage from livestock may occur even after trees are well grown, with the leader out of reach of browsing. Rubbing, horning, and similar activities result in broken branches or ruptures in the bark through which disease may enter.

Damage to Conifers from Browsing. Browsing damage varies with local conditions. Degree of damage is determined by species of tree (especially whether deciduous or evergreen), condition of other forage, season of the year, and climatic conditions.

Deciduous species are in general more attractive forage than are conifers. For this reason, damage can be much more severe in hardwood forests than in the softwood. This, in the case of western and southern forests, is fortunate since coniferous species are the more important timber.

On western ranges, only in the Southwest does there appear to be a problem of magnitude. Here ponderosa pine sometimes is heavily browsed by livestock as well as by game animals. This damage is not associated with great palatability of ponderosa pine but appears to be attributable to the climatic conditions which result in a period during which only sparse dry forage is available from other sources. During late spring and early summer, before forage develops from the midsummer rains, forage, and especially succulent forage, is in short supply. During this period the relatively succulent needles of ponderosa pine may be important items of diet. Especially is this true where animals are allowed to congregate, or when overstocking is permitted. Great concern was felt over the damage to ponderosa pine reproduction in the early years of administration of the national forests. With more orderly management and reduction in livestock numbers, it was found that damage was not so great as was at first supposed. Death loss of seedlings due to browsing has been found to be about 4 per cent from sheep and less than 1 per cent from cattle. However, repeated browsing of young trees results in retarded growth rates (30).

Although the browsing problem is most severe in the Southwest, the same phenomenon may occur in the southern pine areas. Here lack of succulent forage during the winter may result in conditions that make foliage from young pines attractive as forage for cattle (3). Hog rooting is a major problem in parts of this region (Fig. 99, page 282). Foraging upon other coniferous species and in other regions seems not to be of great importance (25, 32, 35, 41).

Damage from Foraging upon Hardwoods. Different problems are encountered where the important tree species are hardwoods. The foliage of these species is much more attractive to animals than that from conifers. Moreover, the dense canopy formed by well-developed hardwood stands results in but small amounts of undergrowth to provide forage for livestock. Since commercial hardwood stands do not occur in the West, the problem is confined to the eastern half of the United States and, except for the Ozarks, largely east of the Mississippi. Generally, the timberlands grazed are small farm wood lots.

Grazing on farm wood lots is a common practice. In many instances, grazing is intense, and the land is expected not to provide subsistence but only to serve as a holding pen, the major portion of the animal's diet being supplied from other sources (12). Oftentimes the wood lot is in connection with a pasture, the wood lot being utilized as a resting and shading area. Under such conditions, every vestige of green material within reach may be removed. Grazing to such intensities has a deleterious effect upon both tree reproduction and soil (Table 40).

TABLE 40. A COMPARISON OF WOODLAND SOILS, GRAZED AND UNGRAZED
Data from Chandler (4)

Treatment	Organic matter, per cent	Volume weight, grams per cubic centimeter	Moisture equivalent, per cent	Field moisture content, per cent
Grazed	6.40	1.15	32.0	10.6
Ungrazed	8.50	0.92	36.8	14.4

Observations of grazed wood lots have shown them to be lacking in reproduction (5, 37), and the growth rate of the timber is believed by some to be lessened (10). Furthermore, grazing favors the less desirable or weed trees over better species. Continued grazing results in the formation of a heavy sod, which further discourages the reproduction of trees (11, 13). There appears to be little justification for grazing farm wood lots, owing to their low value as pastures and the harm done to tree reproduction.

The Ozark region is one in which hardwood forests are grazed under open-range conditions. Although there has been considerable damage from grazing during past years, the damage may be reduced to negligible proportions by proper management. This requires closing the area to grazing during winter months and reduction of numbers to achieve moderate grazing pressures (19).

Damage Due to Trampling by Livestock. Browsing is but one source of damage. Compaction of the soil and uprooting or mechanical damage to young trees are equal sources of concern on potential timberlands. In coniferous stands, except in ponderosa pine forests, damage from this source is more serious than from browsing. However, it is probably not of serious proportions, except in areas where livestock are permitted to congregate. Studies made on sheep ranges in western white pine forests revealed that, although some damage due to trampling occurred, this was limited to seedlings under 5 years of age. Furthermore, the damage was small except on driveways, and in no case was it such as to reduce the number of seedlings below that needed to establish an adequate timber stand (41). Similarly, it has been observed that sheep, while doing some damage, especially on heavily-grazed areas of western yellow pine, were of minor importance as compared to the other causes of seedling mortality (36). Many observers have failed to find evidence of material damage except on areas of heavy concentration (2, 20, 22, 26).

Relationship of Kind of Stock to Forage Damage. Damage to tree reproduction by sheep and goats is more severe than by cattle (3, 17, 28, 31). Since sheep show greater preference for browse forage than do cattle, the incidence of browsing on trees is somewhat higher. Moreover, if they are carelessly handled and close-herded, trampling damage can be severe. With proper consideration to availability of other forage and with moderate stocking rates, it is doubtful if material damage would occur in coniferous forests either from cattle or sheep. Goats may need to be excluded from timberlands (10), and certainly uncontrolled hogs are not desirable on any timberland.

Beneficial Effects from Grazing. The relationships between tree reproduction and grazing animals are not all harmful. Heavy utilization, even to the point of overgrazing, actually may favor germination as has been shown in both ponderosa pine and white pine types of Idaho, where bed grounds and driveways had more seedlings than lightly grazed areas (36, 41). Trampling may aid germination by reducing heavy litter and forcing seed into moist mineral soil. No gain may be secured, however, if the heavy use is prolonged after seedling growth is under way. After the seeds have germinated, however, moderate grazing may again serve to aid survival by reducing competition from herbaceous plants. Survival of Douglas fir in the Northwest has been observed to be greater under

moderate grazing than on ungrazed areas (20). A study in the Southeast reported greater survival of pine seedlings as a result of grazing and also more rapid growth during the first 3 years (35). Close grazing for 5 or 6 years after a good seed crop, followed by lighter grazing, has been recommended as a means of insuring greater survival of ponderosa pine (29).

Grazing and Fire. Grazing may have an effect distinctly beneficial to the forest in that it reduces inflammable matter on the ground (16). The result is decreased fire hazard and less damage when fires do occur. In the southern pine region, grazing reduced losses of seedlings on burned areas because it reduced inflammable material adjacent to the trees (39). The reduction in inflammable material results from consumption of herbage as well as changes in the kind of vegetation, tall rank species giving way to lower-growing forms that constitute lessened fire hazard (2).

Unquestionably, indiscriminate burning with the sole purpose of improving pasture has had harmful effects on timber growth. Both burning and grazing must be managed and controlled to secure beneficial results.

Indirect Effects from Grazing Timberlands. Considerable evidence exists to suggest that there may be indirect effects of livestock grazing in forests which are fully as important as the direct. An apparent increase in the incidence of tree diseases in western forest areas may be due in some cases to the increase of alternate host plants under heavy grazing. White pine blister rust is believed to have increased, owing to spread of *Ribes* by grazing animals (41). Other similar relationships are suspected. It is possible that influences of this sort may be of greater significance than are those associated with direct injury to trees.

At least one harmful result of timber grazing in which the grazing animal is the victim is reported. Browsing upon ponderosa pine has been found to cause abortion among range cows in western Canada and neighboring states (24).

WATER AND RANGE LIVESTOCK GRAZING

All water which is available for man's use must be delivered to the land by means of precipitation. Without this means to recharge water supplies, there would be no streams and no ground water to be tapped by wells. Throughout most of the West, a surplus of precipitation to recharge ground-water supplies occurs only in mountain areas, the same areas that are used for grazing. Furthermore, the disposition of precipitation is markedly influenced by the presence or absence of vegetation which in turn is determined by grazing use.

Water, in the West, is wealth (Fig. 76). Irrigation water is essential to the production of crops over by far the greater part of the West and

hence is essential to a proper balance between range and farm forage production. No less important is the role of land in furnishing culinary water to man. The realization of this has led many cities to purchase watersheds and to prohibit cultivation, grazing, and tree cutting. Millions of dollars have been expended to obtain water from new watersheds, often at great distances, because of misuse of the nearby natural watersheds.

FIG. 76. Nature designs streams to flow clear and regularly through vegetated channels. This stream drains an area which has not been grazed for 50 years.

In areas where precipitation exceeds water loss, there are flowing streams, and through proper conservation practices these streams can be made to furnish water to arid lands. Stream-flow values have been calculated as high as $12 to $97 per acre of range watershed (8). In the United States there are invested many billions of dollars in buildings, machinery, reservoirs, and land that would lose their value if the land were deprived of irrigation water. Much of this water comes from range land, and its protection is a vital duty of the range manager.

The 355,000-acre irrigated area surrounding Boise, Idaho, derives its

water from a drainage area of 1,700,000 acres. There are invested in this area about $32 for each acre of the watershed (15, 33). This watershed is low-value range land whose major use should be water production. Jeopardizing such an important watershed by excess grazing would be foolhardy; if the two uses are not compatible, then grazing should be discontinued.

The Hydrological Cycle. The process of continual transfer of water from land and ocean surfaces to the atmosphere and back is diagrammed in Fig. 77. Vegetation is seen to stand between the atmospheric moisture

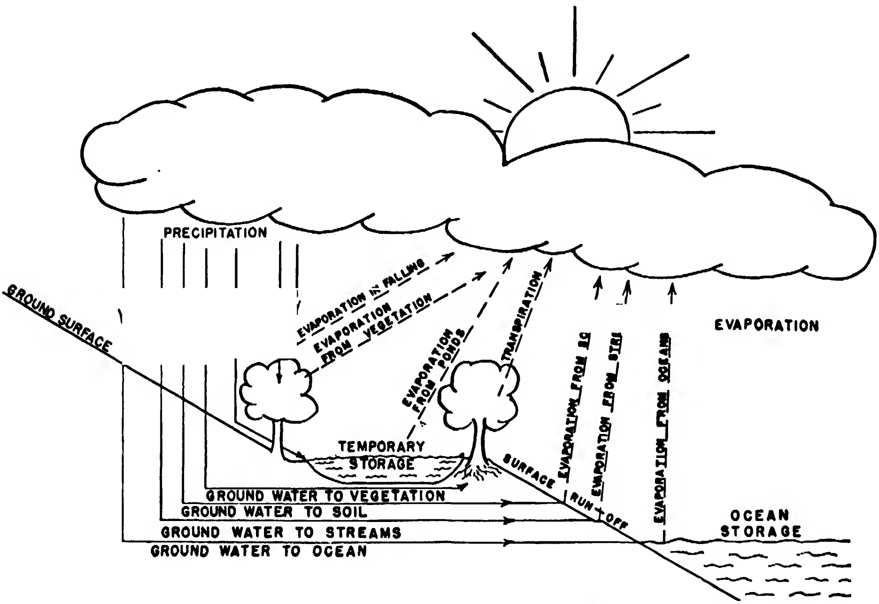

FIG. 77. The hydrological cycle showing transfer of water from land, plant, and ocean to the atmosphere and back.

and water bodies between which the greater part of the moisture circulates. It is here that land use with its modifications of vegetation and soil alters the hydrological cycle. Infiltration may be great so that a large percentage of the precipitation penetrates to ground water, ultimately appearing as spring flow, or to be recovered through wells. In contrast, surface runoff may be high, with peak flows immediately after storms and accompanied by erosion and soil loss. Less spectacular but of great significance in the water economy is the effect that land use may have upon water yield by its influence, through vegetation modification, upon evaporation and transpiration losses. Unfortunately we know little about the relationships which exist between grazing and these phenomena. Much better documentation exists with respect to surface runoff and soil erosion.

Transpiration and Evaporation. Vegetation can be produced only through the expenditure of water. Although vegetation reduces the amount of evaporation from the soil, the aerial portions intercept part of the precipitation and return it to the atmosphere. That which penetrates the vegetal canopy and enters the ground can later be absorbed by the roots and returned to the atmosphere by transpiration. The magnitude of the amounts of water involved can be appreciated from contemplation of the *water requirement* or ratio between amount of water transpired and amount of herbage produced. For native vegetation this ratio is about 700 to 1, which means that growth of a ton of herbage would entail the transpiration of 700 tons of water, or over 6 acre-inches. For a heavy forest stand in the Southeast, this transpiration loss has been determined to be from 17 to 22 inches (18). Lower values may be expected from less dense vegetation and under lesser precipitation. Losses from aspen stands in Utah due to evaporation and transpiration were 16 to 20 inches; losses from herbaceous vegetation were from 12 to 18 inches. The losses in excess of that from bare soil were about 8 and 4 inches for aspen and herbaceous cover, respectively (9). These indicate the magnitude of the cost in terms of water loss for maintaining a vegetation cover to control runoff and erosion. Whether or not grazing to reduce foliage may measurably reduce loss of water through transpiration has not been adequately determined. Possibly grazing may increase water yield without impairing stream-flow behavior.

Infiltration. Water which reaches the soil surface infiltrates the soil until the rate of application exceeds the rate of infiltration, after which the excess moves laterally as *surface runoff*, also called *overland flow*. At any instance and place the capacity of soil to absorb water has a definite limit. This limit is determined by many factors, among which are soil texture, soil structure, soil-moisture content, and length of time that water has been applied. Coarser-textured soils absorb water more readily than do fine-textured soils. Fine-textured soils may be made more absorptive through improvement in their structure. Small particles grouped together to form aggregates act like larger particles. The ability of a clay soil to absorb water may, through alterations in its structure, become comparable to that of a sandy soil.

Characteristically, infiltration rates are highest at the beginning of water application, decreasing steadily to attain a nearly constant rate. While this constant rate may be limited by subsurface layers or by saturation of the soil mantle, very often it is determined by the condition of the soil surface. Figure 78 shows characteristic infiltration curves.

It has been observed earlier that vegetation plays a major role in forming and determining the character of the soil. The vegetation also determines to large extent the infiltration capacity. Moreover, it has

pronounced effect upon the preservation of a permeable soil surface under the impact of precipitation. This is accomplished through the interception of the raindrops by the vegetal canopy and by the accumulated litter and plant residues, thus dissipating the energy of fall. Such mechanical intervention serves to prevent puddling of the soil surface which results in closing the channels against water penetration. Infiltration, therefore, is maintained at a high level under vegetation, with a consequent reduction in the amount of water appearing as overland flow.

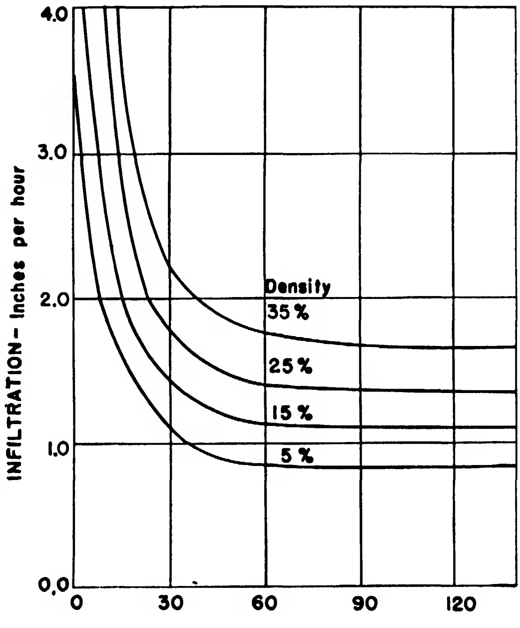

FIG. 78. Infiltration has a high initial rate which drops to a nearly constant one. The curves show the effect of density of browse cover growing on a sandstone soil in keeping infiltration rates high. (*Data from Woodward, Lowell. Infiltration capacities of some plant-soil complexes on Utah range watershed lands. Trans. Amer. Geophys. Union, Part* II, *pp.* 468–475, 1943.)

Effects of Grazing upon Infiltration and Runoff. Grazing may be expected to alter the natural infiltration-runoff relationships by reducing the protection afforded by herbage, by reducing and scattering the litter, and by compacting the soil through trampling. The magnitude of these changes is determined by the intensity of the grazing as well as by soil type, climate, topography, livestock management, and vegetation type. Little information exists which might serve to indicate safe grazing levels under the many conditions which exist on watersheds. Ample evidence, however, has been accumulated to demonstrate that heavy and indiscriminate use may have serious implications.

Soil structure is altered materially by heavy grazing (Table 40). In comparing undergrazed, overgrazed, and depleted ranges in New Mexico, Flory found a pore space of 68.1, 51.1, and 46.5 per cent, respectively. The inches of water penetrating per hour were 4.14, 2.16, and 0.82, respectively (14).

Research on the Coweeta experimental forest watershed in North Carolina showed that 9 years of heavy grazing by cattle reduced large pore space in the first 2 inches of soil by 44 per cent and in the 2- to 4-inch depth by 60 per cent. The ability of the top 4 inches of soil to store

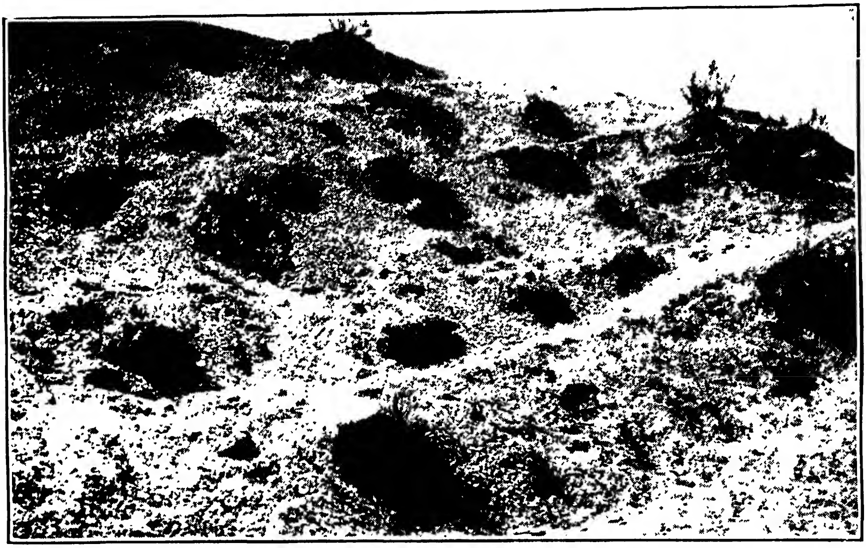

FIG. 79. Range plants ultimately die from overuse by grazing animals. Soil thus exposed erodes rapidly and may literally flow over and bury other plants.

water was thus reduced from 1.2 inches of water to 0.5 inches, and permeability was only about one-tenth that of comparable ungrazed forest (38).

Forest Service tests on Idaho range lands using artificial rain machines were made on four types of vegetation, as follows: (*a*) wheatgrass (*Agropyron spicatum*), representative of the grassland climax; (*b*) lupine and needlegrass (*Lupinus* and *Stipa lettermanii*), perennials representative of an early stage of depletion from grazing; (*c*) annual grass (*Bromus tectorum*), a later stage of depletion from grazing; and (*d*) annual weed (*Gayophytum*, *Madia*, and *Lactuca*), an inferior range cover brought about by intense misuse. Average observations for each vegetation type, all other variables having been isolated, are shown in Table 41. It will be noted that, with increased grazing, both runoff and erosion increase. Ultimately the misuse of land can ruin it for grazing (Fig. 79).

TABLE 41. RUNOFF AND EROSION FROM FOUR VEGETATION TYPES OF SOUTHERN IDAHO

Data from Craddock and Pearse (7)

Vegetation type	Wheat-grass	Lupine and needlegrass	Annual grass	Annual weed
Runoff, per cent	0.4	49.9	25.5	60.8
Soil eroded, tons per acre	0.003	2.38	1.05	7.64

Relationship of Surface Runoff to Erosion. A major significance of reduced infiltration and increased overland flow is the greatly increased erosion potential which results. Erosion varies with the velocity of the water in motion, and the natural erodibility of the soil. Velocity varies approximately as the square root of the slope; thus, increasing the slope by 4 times will double the velocity. Doubling the velocity will increase by 4 times the eroding power (to the second power), by 32 times the quantity of material that can be carried (to the fifth power), and by 64 times the size of particle that can be moved (to the sixth power) (1).

Artificial-rain machines showed that, on range lands having various rain intensities, soil conditions, and plant covers, runoff from 30 per cent slopes averaged 41.24 per cent of the precipitation, and soil losses averaged 1.67 tons per acre. On 40 per cent slopes, runoff averaged 49.52 per cent, and soil losses were 5.71 tons per acre (7).

The factors of slope and soil character are not under ready control of the land administrator. However, management may influence the degree of accumulation of water, which in turn affects the velocity of flow. The velocity of water which collects in a channel 6 inches wide and 6 inches deep will be approximately 2½ times the velocity attained if the same volume of water is kept spread over a strip of land surface 36 inches in width. Similarly, in the absence of a channel, the increase of water depth on the ground surface from ¼ to ½ inch would have the effect of increasing the velocity of flow by 1.2 times. The range manager must, therefore, graze not alone with the idea of the welfare of the livestock but also must consider the effect of use upon the disposition of precipitation and resultant erosion.

Ground-cover Requirements to Prevent Overland Flow and Erosion. Little is known of minimum vegetation requirements to prevent critical water losses during storms. Under adverse conditions, as in cases of steep slopes, erodible soils, and intense storms, a considerable protection is required. Occasionally under such situations no impairment of vegetal growth through grazing may be permissible. Under less critical situations, completely satisfactory watershed conditions may exist under full use by grazing animals. Packer concluded that ground-cover densities,

including living plants and litter, should be at least 70 per cent to achieve adequate protection to the soil surface on erosive mountain lands in southern Idaho (27). A ground cover of 65 per cent was considered necessary (23) in northern Utah mountains (Fig. 80).

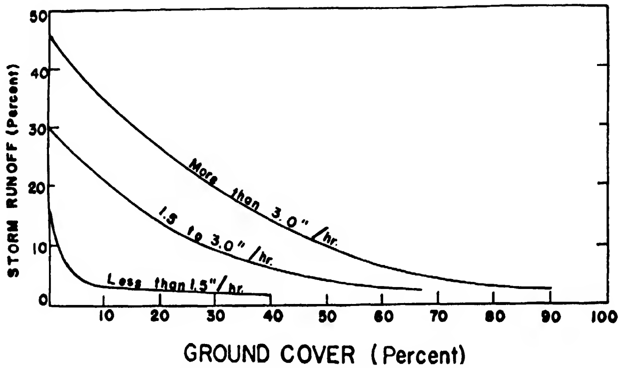

FIG. 80. Relation of summer-storm runoff to total ground cover under low-, moderate-, and high-intensity rainfall. [*Data from Marston* (23).]

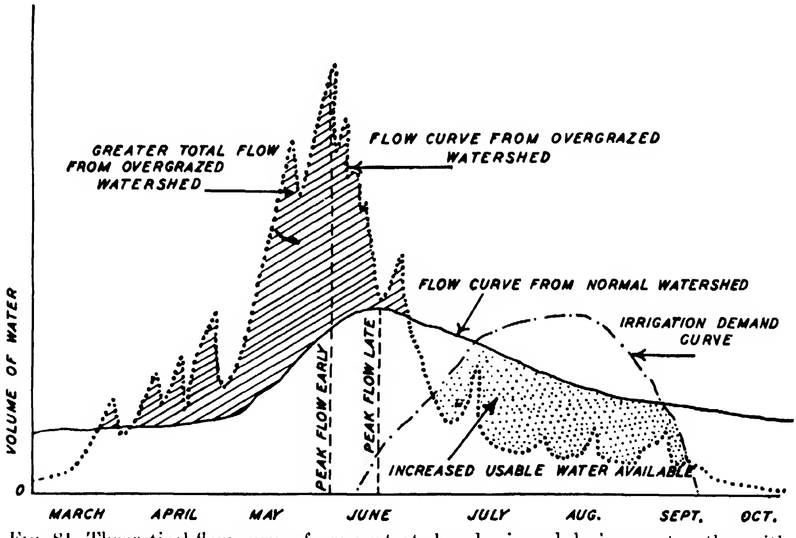

FIG. 81. Theoretical flow curves from protected and misused drainages, together with irrigation-water-demand curve.

Effect of Grazing upon Time Distribution of Stream Flow. Recognition of the fact that vegetation uses water has led to proposals to graze heavily to reduce transpirational losses. The contention has been that more water is obtainable from an unvegetated slope than from a vegetated one. In one instance, prominent citizens and officials actually petitioned govern-

ment land administrators for more intensive grazing of the forage on watersheds adjacent to their communities under the premise that more water would be available for irrigation. This idea contains some truth. It fails, however, to consider the possible deterioration of the watershed through erosion and the threat of floods and damage to adjoining properties. Moreover, greater water flow may mean less, not more, usable water.

Hypothetical water-flow curves in Fig. 81 show that the demand for irrigation water comes late in the summer. Water flow from an undisturbed

FIG. 82. This flood water carries tremendous quantities of soil and organic matter from a range area already pitifully depleted. Water so lost cannot benefit the range. At the time this photograph was taken the water was carrying 6.7 per cent silt. Soil was passing down the stream at the rate of 17,500 tons per hour, of which 500 tons was organic matter.

drainage more nearly coincides with this demand period than does the flow from misused watersheds. Not only does such flow come too early for irrigation, but also it may contain quantities of silt so great as to interfere seriously with irrigation. Vegetation works on the same principle as does a storage reservoir in decreasing the silt content of water and delaying flow.

SOIL-EROSION PROCESSES

Loss of soil by washing and blowing usually follows deterioration of vegetation. As soil becomes less abundant and increasingly compacted with misuse of the land, decreased water infiltration and increased runoff are inevitable (Fig. 82).

Soil and water conservation are inherent to good range management, the two being inseparable. Range land, when it is properly grazed, is in balance with the eroding forces. Since western ranges are arid and slow to recover from misuse, a balance of water and soil does not always follow immediately in the wake of improved grazing practices. Special soil-conservation practices may aid in attaining this balance, but generally range-soil conservation is attained through good range management.

Erosion may be divided into two distinct classes: (*a*) geologic, or normal, and (*b*) accelerated, or induced. Geologic erosion is that which takes place naturally and over which man has comparatively little control. Accelerated erosion is that which progresses at a rate faster than normal because of the activity of man. It is erosion in excess of geologic erosion. Great skill sometimes is necessary to determine when soil and water losses are excessive.

Geologic Erosion. Nature maintains a delicate balance between forces that act to level the landscape and others that tend to hold the soil in place. The eroding forces are water, including translocation and leaching; wind; and glacial action. The major force tending to hold soil in place is vegetation.

The forces concerned in erosion tend to level the earth's surface. As the surface becomes more level, rate of geologic erosion decreases, the rate being maximum on steep topography. A climax vegetation cover indicates slow geologic erosion, for nature has come to a point of relative balance. Local yearly variation typical of western climates results in rapid erosion since vegetation cannot so rapidly adapt itself to changing conditions. Vegetation is reduced by subnormal precipitation over a period of a few years, and if this is followed by abnormally high precipitation, erosion is severe.

Geologic erosion is progressing at a rapid rate in much of the western United States as evidenced by steep slopes, immature soils, and large areas of subclimax vegetation. On few areas is all erosion accelerated, and sometimes extensive soil movement may occur, even though the area is not abused. The range manager should remember that, even before the white man, erosion was rapid, floods were frequent, and hillsides were bare in parts of the arid, mountainous West. Erosion is the result of numerous factors, and perhaps it matters little whether these factors are natural or whether they result from man's use or misuse of the land. Still, in studying erosion the student should be aware of the fact that man is but one of the factors determining rate of erosion.

Accelerated Erosion. Accelerated erosion occurs when the stabilizing vegetation is destroyed by man and is no longer able to hold soil against the eroding forces of nature. Such erosion is an aftermath of vegetation regression and may be delayed considerably thereafter. Likewise, once

erosion has occurred, reoccupation by climax vegetation may be delayed decades awaiting rebuilding of the soil (Fig. 83).

Accelerated erosion is divided into two types, offering distinct and different problems- water erosion and wind erosion. Water erosion may be sheet erosion, in which a uniform layer of soil is removed, or gully erosion, in which distinct channels are formed (Fig. 84). Water erosion is closely affiliated with water losses, thus effecting a dual loss; but the soil damage of which wind erosion is capable is so great as to make it only slightly less important.

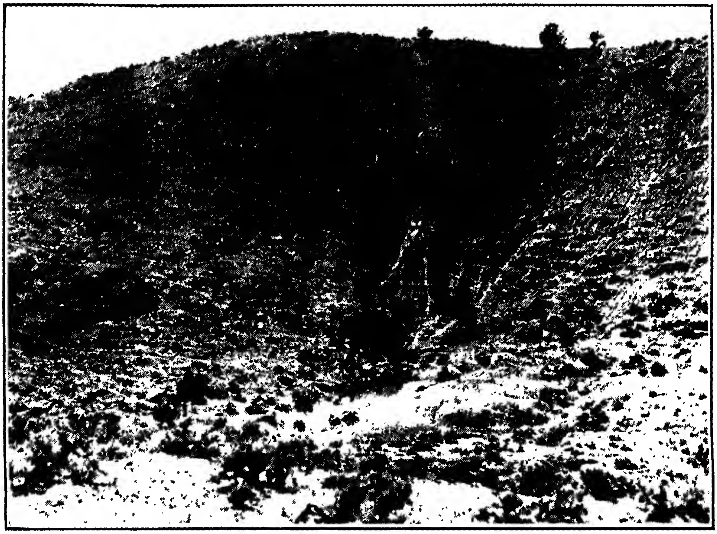

FIG. 83. A crisscross of erosion rills and sheep trails on the hill tells its own story.

There are four factors important in determining rate of erosion: climate, topography, kind and depth of soil, and vegetation. Since climate and topography are relatively stable, we must look to soil and vegetation for the cause of acceleration of erosion.

Cultivation often breaks down the natural structure of soil, leaving a powdery surface and a packed subsoil. Fertility changes, especially organic-matter changes, are important in that they influence the structure and water-holding capacity of the soil. Some important structural changes also accompany grazing, especially during the early spring months when the soil is wet and can be readily packed. Runoff and washing from mature soils almost never become severe so long as the soil retains its virgin structure and organic matter.

Fire has altered the vegetation over a vast area of the West. Clean cutting of forests has been responsible for many changes. Similarly on

range land, sometimes not even a remnant of the former cover remains because of heavy grazing or burning. The invading secondary plant cover is almost without exception inferior in erosion control.

Wind Erosion. Dust storms in the southern Great Plains in the period 1934–1936, and again in 1954 and 1955 show how land misuse coupled with unusual drought brings about an unbalance in nature of tremendous significance.

FIG. 84. A tremendous gully head caused by runoff from overgrazed semidesert range land.

Despite the apparent differences that exist between water and wind erosion, it is surprising how analogous are the causes, results, and cures. Wind erosion, in serious form (Fig. 85) is confined to arid regions, usually below 15 inches of precipitation, the most important reasons being that vegetation is more sparse, humidity of the atmosphere is lower, and hot, bare soils cause rising air currents, which lift soil particles upward into the atmosphere. Though organic matter itself is light and subject to blowing, it tends to bind soil particles and to make them more stable. Likewise, a high organic content means a high water-holding capacity,

which decreases blowing. Wind velocity is greatest on level prairies. Topographic irregularities and vegetation, especially trees, greatly decrease wind.

Vegetation is the most vital single element determining rate of soil blowing. It indirectly influences soil structure, soil organic matter, soil moisture, atmospheric humidity, and wind velocity. It is through these media, together with mechanical binding of the soil particles, that vegetation protects soil from blowing.

Fortunately, soil drifting starts not over a wide area but at a small focal spot or infection center, from which it spreads rapidly. These

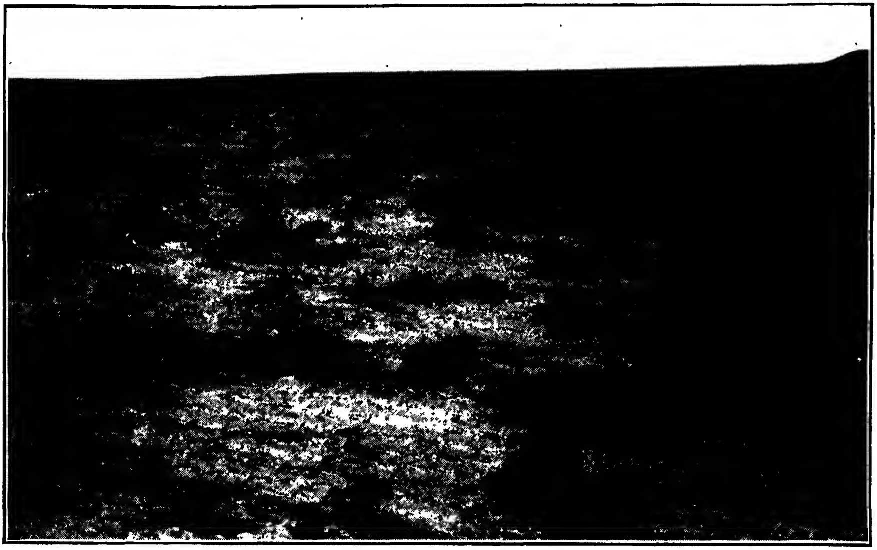

FIG. 85. Flying soil particles borne by wind may actually cut vegetation to shreds, leaving nothing but dead stumps.

blowout spots head out much the same as gully heads. The partial vacuum created as wind passes over the small depression causes an upward-swirling air current, which carries soil particles and causes an increasingly deep and wide blowout hole. The material is carried until the air velocity is decreased, whereupon the larger particles settle out to form dunes along fences or any other obstruction. These dunes are rolled by the wind, material from the windward side being deposited on the protected leeward wide (Fig. 86). Finer particles may be carried for hundreds of miles.

Prevention of wind erosion is not difficult; but when it has progressed to the stage of active soil movement and widespread depletion, the cure is one of the most formidable problems facing the land ecologist. Nature needs hundreds of years to stabilize shifting sands. Although man, by

the use of mechanical aids, can greatly shorten this time, still vegetation must be the ultimate means of control, and only time can effect the necessarily gradual transition.

Blowing on burned ranges or otherwise denuded land can be checked temporarily by furrowing with a lister or similar plow against prevailing direction of the wind. Land subject to blowing should always be left rough after tillage.

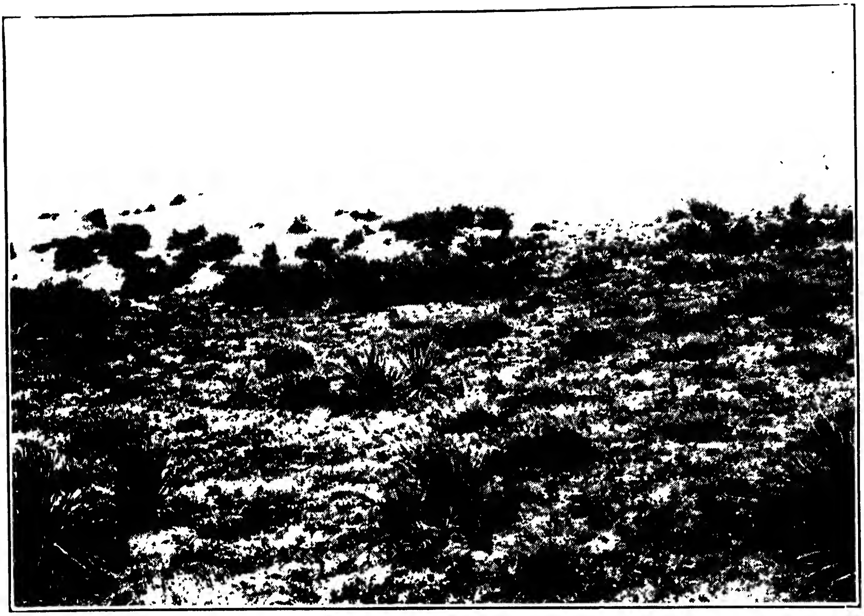

FIG. 86. Severe wind erosion on range land in Texas has resulted in active dune formation. Overgrazing and drought on areas of sandy soil cause this condition. The vegetation is largely annual forbs and soapweed (*Yucca* spp.), together with a small amount of perennial grass, including needlegrass (*Stipa* spp.) and fingergrass (*Digitaria* spp.), and annual fescue (*Festuca* spp.). (*Courtesy of U.S. Soil Conservation Service.*)

Vegetative Control of Erosion. Since vegetation changes are the primary cause of the acceleration of erosion, vegetation also is the chief weapon in controlling erosion. The procedure of the soil conservationist must be to determine the most advisable land use from a scientific, social, and economic viewpoint. On nontillable land it is necessary to protect the native vegetation by initiating a correct grazing method or a systematic timber-cutting program and, if the native vegetation has been destroyed, to replace it by seeding.

Mechanical means of controlling erosion and runoff are artificial and can never be considered as permanent, for they necessitate continued and expensive upkeep. Vegetation, because it is living, replenishes and

rejuvenates itself. Generally, a mechanical control is neither so effective nor so safe as one involving vegetation.

Blowing may be started because of some local soil condition, such as a sand spot, or by some mechanical disturbance, such as is found in a stock-rolling place, a corral, or a roadway. The small spot can be stabilized readily, but it should be taken as a warning. Existing land-use practices should be investigated and the grazing adjusted. Large blowing areas on range land can most economically be brought under control by removal of livestock. Investigations of the range land of southern Australia (31) led to the conclusion that "erosion and drift were essentially symptoms of maladjustment of stocking" and "the only possible way of preventing the extension of erosion and drift in future years is by controlled stocking. . . ." Where total grazing protection is impossible, the establishment of a good conservative grazing system will result in rapid improvement.

Seeding local blow areas to rhizome-bearing grasses may be desirable. For dry sandy areas, *Redfieldia flexuosa, Calamovilfa longifolia, Agropyron smithii, Elymus flavescens*, and *E. arenicola* are valuable; for wetter areas, such as coastal areas and lake shores, *Ammophila arenaria, Elymus arenarius, Panicum amarum, Poa macrantha*, and *Uniola paniculata* are among the best species.

Maximum production on range land is always congruous with maximum conservation of soil and moisture. No standard of good range management is in disagreement with any standard of soil conservation. On ranges where erosion is potentially severe, soil stability, not forage production, should be the measure of correct use. Though disuse is seldom a necessity, full use frequently is unwise. Good land and vegetation management is the most effective and practical weapon available for conserving soil and moisture on the range.

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CHAPTER 10

POISONOUS-PLANT PROBLEMS ON THE RANGE

Poisonous plants cause great losses on the western range in death of animals and in decreased value, essentially through lesser gains. Undoubtedly losses have decreased measurably because stockmen have learned to recognize poisonous species and have learned how to avoid them or to minimize damage from them. This has been counterbalanced to some extent by increased numbers of poisonous species and increased quantities of the native poisonous species. For example, *Halogeton glomeratus* was introduced to America only about 1935 and now covers millions of acres. Other plants, like *Actinea odorata,* are native but increase with range misuse until they are much more abundant and dangerous than originally.

Range technicians generally have agreed that the proper solution to the problem of poisoning lies, not in the eradication of the plant, but rather in learning how to graze infested ranges with a minimum of livestock losses and in preventing the spread of the plant by maintaining a good cover of native vegetation through good range and livestock management.

Learning to live with poisonous plants is not a new idea. Despite the hundreds of poisonous species, stockmen have learned through experience or scientific reports to hold livestock losses to a surprisingly low figure. Heavy losses from loco (*Astragalus*), larkspur (*Delphinium*), greasewood (*Sarcobatus*), and others have been reported in early years on the western range, and these plants were thought at one time to threaten livestock production on ranges occupied by them. In 1920, at Harper, Ore., 1,000 head of ewes out of a herd of 1,700 head died overnight from consuming greasewood (7). In Utah (25), in 1942, 260 sheep died from lupine in a single day on a range where poisoning was previously unknown. Losses of 200 head of cattle from a single herd were reported from larkspur poisoning in 1913 (16). In 1917, 736 sheep died from a band of 1,000 in western Colorado from milkweed poisoning (18). In Montana 700 sheep died out of 2,000 trailed over a lupine range, and in another herd 1,150 out of 2,500 died from the same poison (5). In 1909, 500 sheep from a herd

of 1,700 died from death camas poisoning in Wyoming and in one county alone 20,000 died from the same cause (5). Other such losses have been reported from New Mexico and Utah from consumption of greasewood, larkspur, and loco (5, 16, 25). Large losses of sheep from halogeton have been recorded. By far the most severe losses were reported in the Raft River region of Idaho in 1945, when 750 animals died from one flock and 275 from another.

Thus, a number of phenomenal losses have occurred from poisonous plants. None of these plants has been eradicated over an extensive area, yet, often the same ranges are grazed today with few or no losses. Stockmen have never found a way to eliminate a single poisonous species on a practical scale. Yet they have learned to live relatively safely with every one of more than 400 known species of poisonous plants in the United States.

PREVENTING POISONOUS-PLANT LOSSES

Poisonous plants, with few exceptions, are not abundant in the climax but are invading species or species that increase with heavy grazing (Table 42). Many are annual, but the majority are perennial species.

TABLE 42. GENERAL ECOLOGICAL STATUS OF SOME IMPORTANT POISONOUS PLANTS

Locally abundant climax constituent	Present in climax but not abundant	Early regression stages	Late regression with severe misuse
Tall larkspur	Death camas	Low larkspur	Milkweed
Arrowgrass	Loco	Rubberweed	Tobacco
Chockcherry	Horsebrush	Saint Johnswort	Nightshade
Lupine	Sneezeweed	Burroweed	Halogeton
Black laurel	Water hemlock		Bitterweed
Oak			
Greasewood			

Most poisonous species kill animals only if eaten in large amounts—often almost a straight diet of the poisonous plants. Where there is plenty of forage, animals naturally vary their diet, hence eating large amounts of any one species is unusual. With few exceptions, a normal range is safe for domestic livestock. Poisoning is nature's sign of a sick range!

Plants do not fall readily into a poisonous and a nonpoisonous group. Probably thousands of plants would be poisonous if eaten in sufficiently large quantity. Some of these are excellent forage when not eaten too abundantly. Many plants definitely classed as poisonous are eaten daily

by animals with no ill effect because they are taken in small amounts and the poison is eliminated by the animal as rapidly as it is consumed. Although a few species, such as water hemlock, are violently poisonous at certain times of the year, even in small amounts, *most poisonous plants are not dangerous, except in large amounts*, and even then they may be harmless at certain times of the year and under certain conditions. Generally, animals do not graze highly poisonous plants from choice and are rarely poisoned when they have an abundance of good forage. Exceptions are the habit-forming species for which the animals acquire a desire. Many loco species (*Astragalus* spp.) are habit-forming.

Most losses from poisonous plants can be attributed to hunger, hunger being caused, usually, by poor range conditions. Another cause of unusual hunger is placing animals on the range in early spring before growth is well started. Because poisonous plants often are early-growing, they may be consumed in large quantities before good forage becomes available. Hunger may result from confinement in corrals or barren driveways and from rapid driving, even over relatively good forage, if the animals are given no time to eat. Scarcity of forage around overused bed grounds, trails, salt grounds, and water holes may force animals to consume forage species ordinarily ignored or eaten only in small amounts.

General Management Rules to Prevent Poisoning. Prevention of poisoning is much more easily accomplished than is curing an animal. Although management is not a complete solution to the poisonous-plant problem, in most instances it is all that is economically feasible. A few rules of good range management and livestock husbandry, if carefully followed, will prevent the majority of losses.

1. Do not misuse the range so as to bring about the invasion of new species, for these invading plants may be poisonous species. Misuse also encourages spreading of poisonous species which may exist already on the range in amounts not dangerous to animals.

2. Avoid areas where poisonous plants are abundant. Animals always concentrate at and overgraze water holes, salt grounds, bed grounds, and trails. Avoid as much as possible grazing such places because these overgrazed areas are likely to grow poisonous plants. Move sheep away from water holes as quickly as possible after drinking. Use new bed grounds each year and occupy them only for two or three nights at a time. Move cattle salt grounds frequently. When possible, avoid established trails, and drive animals slowly, so they can select forage rather than seize it in passing. Small areas of poison may be fenced and not grazed, at least during dangerous seasons of the year. Much can be accomplished by teaching livestock operators the major poisonous species and educating them as to dangerous seasons and kinds of stock affected. A herder, once he knows where the poisonous plants grow and when his animals are in

danger, can do much to prevent damage. This seems fundamental to good herding.

3. Do not force animals to remain on the range after they have utilized the good forage species, or ultimately they will turn to the less desirable and, often, poisonous ones.

4. Do not allow animals on the spring range until the good forage species have made sufficient growth to support them; otherwise, they may be forced to consume the early-growing poisonous species. Some species are more poisonous in fall, others while in fruit, still others in spring. These factors should be considered in grazing plans.

5. When animals have been on dry feed, or after they have been deprived of forage, as during shipping, trailing, or corralling, they should not be put on ranges containing poisonous species until they are well fed.

6. Use plenty of salt; shortage of salt may cause animals to eat plants not normally eaten. Shortage of other minerals, especially phosphorus, induces abnormal appetite, usually evidenced by bone chewing. Animals so affected are sure to eat abnormally of low-value vegetation such as poisonous plants. Feeding bone-meal supplement has been shown to reduce poisoning losses.

7. Graze with the kind of stock not poisoned by the plant in question. Many plants seriously poisonous to one kind of animal are not poisonous to another, or, at least under practical range conditions, are not dangerous.

8. Poisonous plants sometimes may be eradicated by grubbing or spraying where economical. Little progress has been made in developing effective methods of eradication that are not costly far in excess of the grazing value to be gained. (See also *Spraying Range Weeds*, page 353.)

CURING POISONED ANIMALS

Treating poisoned animals on the range is always a last resort and never should be relied upon as a solution to the problem. The help and advice of a veterinarian is always desirable. In some cases he can save many animals that otherwise would die. Generally, however, this help comes too late. Always get all animals off the range when poisoning first becomes evident. If possible, take sick animals to a corral and feed them on good laxative feed. If they are down, turn them with head uphill where possible. Then call the veterinarian.

Poisoning by some species can be checked very effectively by special drugs; but, in most cases, these are not practical for the stockman to use. Many poisons act so rapidly that cure is impossible if the animal has consumed a lethal quantity. If the animal is not killed, it often returns to normal with no treatment. Putting a sick animal on good feed and leaving it alone frequently is the best cure.

POISONOUS PLANTS OF MAJOR IMPORTANCE

Despite the hundreds of species that are known to contain poisonous or toxic principles, but few are dangerous, especially under conditions of good management. Major poisonous plants of America are given in Table 43. Most of the so-called poisonous species are toxic only when

FIG. 87. Low larkspur (*Delphinium* spp.) is probably the most important poisonous plant for cattle on the western range. Note the palmately divided leaves and spurred blue flowers.

consumed in immense quantities. Because most poisons are not cumulative, they are eliminated before the consumption has become sufficient to be lethal.

The following plants are only a few of the dangerous ones, but they are considered the most serious.

Delphinium. The genus *Delphinium* probably is the most important poison for cattle. Sheep ordinarily are not poisoned. Its importance is attributable to great abundance, large number of poisonous species,

relatively high palatability, and wide distribution. The plants are easily recognized by their spurred flowers and palmately divided leaves (Fig. 87). The genus may be divided into (*a*) low larkspurs, having ephemeral habits and typical of foothills, and (*b*) tall larkspurs, green throughout the summer and typical of high mountain ranges. Both forms are poisonous, though the tall is not ordinarily dangerous after fruiting. It is safer

FIG. 88. Death camass (*Zygadenus paniculatus*) is characterized by a deep, odorless bulb and white flowers.

to graze after the first of August, though poisoning may occur thereafter in exceptional instances.

Though the larkspurs are highly poisonous to cattle, it is necessary for the animal to consume 1 to 3 per cent of its weight to be poisoned, a quantity that would be consumed only under exceptional circumstances. A protein supplement in the early-spring grazing season is said to reduce poisoning (1).

Zygadenus. The genus *Zygadenus*, commonly called death camass, is among the most important of the sheep poisons in the West. Cattle and horses are susceptible but ordinarily do not consume enough to be

TABLE 43. POISONOUS PLANTS IN SUMMARY

Name	Location and habitat	Dangerous Season	Grazing Animal Endangered	Poisoning Conditions and General Information
1. Arrowgrass (*Triglochin maritima*)	Wet and alkaline bottomlands and seacoasts.	All	All	Hydrocyanic acid. Dangerous when frozen or in drought.
2. Azalea (*Rhododendron occidentale*)	California mountains. wet places. acid soils.	All. especially spring	Sheep	Few ounces of leaf poisonous. Unpalatable.
3. Bitterweed (*Actinea odorata*)	West Texas and west to California. misused land.	Winter to summer	Sheep	Cumulative, unpalatable annual. Overgrazed range. Dry years.
4. Black laurel (*Leucothoe davisiae*)	California mountains, acid soil, moist sites.	Winter. spring	Sheep	0.2 lb. per day fatal, evergreen, shrub.
5. Bracken fern (*Pteridium aquilinum*)	Woodlands throughout U.S., burned land, rich soil.	Fall, even hay	All. especially cattle and horses	Cumulative poison, large amounts. Unpalatable.
6. Chokecherry (*Prunus* spp.)	Roadsides and valley bottoms, mountains.	All	All, especially sheep	Large quantities, dangerous when frozen or wilted. Hydrocyanic acid.
7. Cocklebur (*Xanthium* spp.)	Fields and waste areas, wet places throughout U.S.	Spring	All, especially cattle and pigs	0.75 per cent of body weight, not cumulative. First leaves or cotyledons, old plants safe.
8. Copperweed (*Oxytenia acerosa*)	Colorado River drainage, dry washes. and alkali flats.	All, especially fall	All, especially cattle	Dangerous on fall trail. Compositae, 3 ft. high, in clumps.
9. Coyotillo (*Karwinskia humboldtiana*)	Southwestern Texas, dry lands, gravelly hills.	All. especially in fruit	All	Large shrub. Black fruit very toxic. Continued paralysis. Slow-acting poison.
10. Death camass (*Zygadenus* spp.)	Foothills and wetter desert lands of Western U.S.	Early spring	All. especially sheep	Dry by early summer. White flower, odorless bulb, 0.5 per cent of weight.
11. Drymary (*Drymaria* spp.)	Misused, dry range, West Texas, Arizona, and New Mexico.	All	All, especially cattle	Unpalatable, 0.5 per cent of weight. Annual 3 inches high, increasing from overgrazing.
12. Dutchman's-breeches (*Dicentra cucullaria*)	Woodlands of northeastern U.S.	Spring	Cattle	Trembling. Blue flower. Unpalatable, shortage of feed.
13. Greasewood (*Sarcobatus vermiculatus*)	Western U.S. alkaline bottomlands and washes.	Spring	All. but mostly sheep	Oxalic acid. Large quantity on spring trails, eaten alone.
14. Halogeton (*Halogeton glomeratus*)	Salt deserts, northern intermountain region.	Fall, winter	All, but mostly sheep	Oxalic acid. Very unpalatable annual. Misused ranges.
15. Horsebrush (*Tetradymia* spp.)	Intermountain region. mostly dry semideserts.	Spring	Sheep	Spring trail, bighead, photosensitivity. Early yellow flower.
16. Horsetail (*Equisetum* spp.)	Wet meadows and mountains, western U.S.	Hay	All. especially cattle and horses	Slow, habit-forming. Leafless, harsh texture, cone-bearing. herb.
17. Larkspur (low) (*Delphinium* spp.)	Foothills, deserts and plains.	Early spring	Cattle	6- to 12-inch ephemeral. tuberlike root. Graze after June 1.
18. Larkspur (tall) (*Delphinium* spp.)	Mountain ranges.	Early summer	Cattle	4-ft. clumps, hollow stem. Dangerous all summer.

19. Laurel (*Kalmia* spp.)	Moist woods, swamps, mountains throughout U.S.	All, especially winter and spring	All, especially sheep	0.2 to 0.4 per cent of weight. Unpalatable, eaten on overgrazed pastures. Ornamental.
20. Loco (***Astragalus*** and ***Oxytropis***)	Mountains to deserts and plains, western U.S.	All, especially spring	All	Cumulative, habit-forming, some acute poisons, crazed action.
21. Lupine (***Lupinus*** spp.)	Mountain, foothill, and semidesert areas of U.S.	Most when in fruit	Sheep	Pods and seeds of most species dangerous. Palmately compound leaf.
22. Milkweed (***Asclepias*** spp.)	Sandy soils, moist bottoms, waste areas.	All, especially spring	All, mostly sheep	May be poisonous when dry. Narrow and whorled-leaf species dangerous.
23. Nightshade (***Solanum nigrum***)	Waste areas throughout U.S.	Summer	All	Unpalatable annual. Small white flower, black berry.
24. Oak (***Quercus*** spp.)	Foothills, sandy soils, Colorado, Utah, and Southwest.	Spring only	All, especially cattle	Many species dangerous as straight diet, emaciation. Buds and new leaves.
25. Oleander (***Nerium oleander***)	Roadsides and woods, southern U.S.	All, even dry	All	Small quantity. An ornamental shrub.
26. Paperflower (***Psilostrophe*** spp.)	Arizona, south Utah, west Texas, and New Mexico.	All, especially spring	Sheep	Emaciation. Unpalatable, overgrazing, slow poisoning.
27. Peganum (***Peganum harmala***)	West Texas and New Mexico, introduced.	All	All	Unpalatable, 3-ft. perennial, large white to yellow flowers.
28. Poison bean (***Daubentonia*** spp.)	Gulfcoast, Florida to Texas, sandy soils	Mostly winter	All	Seeds poisonous, leaves slightly. Small shrub, legume.
29. Poison hemlock (***Conium maculatum***)	Waste areas, roadsides, moist ground, all U.S.	All, mostly spring	All, especially cattle	Unpalatable, purple spotted Umbelliferae. Introduced. Rank odor.
30. Rayless goldenrod (***Aplopappus heterophyllus***)	Texas, Colorado, New Mexico, Arizona, along springs and waterways	Green and dry	All	Perennial. Causes trembling. Cumulative poisoning.
31. Rubberweed (***Actinea richardsonii***)	Dry mountains, Colorado, Utah, Arizona, and New Mexico.	Spring and fall	All, especially sheep	Cumulative. Unpalatable perennial, small yellow-rayed head. Overgrazing.
32. St. Johnswort (***Hypericum perforatum***)	Waste places, northwestern U.S., invading ranges.	All	All, especially white	Photosensitivity, dermatitis. Rhizomes, aggressive competer.
33. Senecio (***Senecio*** spp.)	Species worldwide, various habitats.	Spring and summer	All	Some species poisonous in large amount, many cumulative.
34. Snakeroot (***Eupatorium rugosum***)	Woodlands, rich soils, eastern U.S.	All, especially fall	All	Trembling. Several days' feeding. Transmitted to man by milk.
35. Sneezeweed (***Helenium hoopesii***)	Mountains, Montana to Arizona, open areas.	Summer	Sheep	Cumulative. Spewing sickness. Large yellow composite.
36. Sorghum (***Sorghum*** spp.)	Cultivated fields, moist areas, southern U.S., escaped.	All, especially when young	All	Hydrocyanic acid, wilted or frozen. Good forage otherwise.
37. Water hemlock (***Cicuta*** spp.)	Wet meadows, ditch and stream banks, all U.S.	All, especially spring	All, especially cattle	Violent poison, especially tubers. Tops poisonous only in early spring
38. Tobacco (***Nicotiana*** spp.)	Western and southern U.S.	All	All, especially cattle	Rapid. Unpalatable. On overgrazed range. Annual. Sticky leaf.

endangered. *Zygadenus* embraces several species, all of which are poisonous. They are widely distributed and are of the greatest importance on early-spring foothill ranges.

Zygadenus is characterized by white flower clusters and lilylike leaves growing from a deep, odorless bulb (Fig. 88).

The species of *Zygadenus* are all poisonous throughout life, and relatively small amounts of some are fatal, 1 to 2 lb. of the most toxic being sufficient to kill a sheep. *Zygadenus gramineus* is the most poisonous of the common species; *Zygadenus elegans* is not dangerous unless consumed in immense quantities. No remedy has proved feasible for *Zygadenus* poisoning. Allowing the animals to remain undisturbed is recommended.

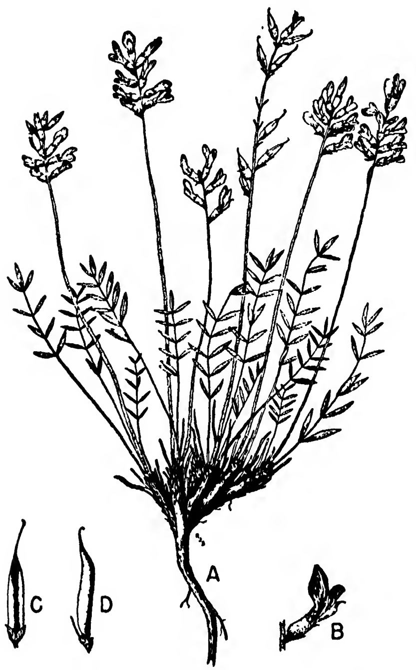

FIG. 89. White loco (*Astragalus lambertii*) showing (*A*) the plant habit, (*B*) the flower, either white or red, and (*C* and *D*) the seed pod when mature. (*From Special Report No. 2, Utah Agr. Expt. Sta.*)

Since *Zygadenus* invades with misuse, good range management offers the best medium of control. Most species dry early in the summer so that delayed grazing frequently alleviates the problem. Herding sheep slowly in open formation, allowing them to select forage as they wish, is helpful. Supplemental feeding, especially of protein feeds, during early spring is recommended.

Astragalus and Oxytropis. These two genera, including loco and poison vetch, are probably as dangerous a group of poisonous plants as occurs in the West. Marsh (15) ranks them as the most destructive of all poisonous plants because they are poisonous to and dangerous to all kinds of stock; also, they are more widely distributed and abundant than any other. There are over 100 species in the West, some being definitely not poisonous, some causing the loco or crazy symptoms, and some being poisonous but not inducing loco symptoms.

The locos and poison vetches are typical legumes having red, white, or purple flowers on crowded racemes and odd-pinnate leaves. They are abundant on the Great Plains and on high mountains and foothills. Most species grow early in the spring (Fig. 89).

Though the locos are probably no more poisonous to one kind of

animal than to another, they are famed from early range days for their effect upon horses. They are among the few plants dangerous to the horse, and the horse seems to develop a fondness for them. Many ranges cannot be used by horses because of loco.

All parts of the plant are poisonous throughout the life of the plant. Much the greatest damage occurs in the spring, when other feeds are scarce. The locos ordinarily are not preferred by animals, which often graze safely on areas that support immense amounts, provided that other forage species are available. Unfortunately, the poison of at least some species is cumulative; hence, animals may be poisoned despite the fact that very large quantities are necessary.

Animals poisoned by loco often exhibit typical crazed actions, lose flesh, and produce abnormally long hair. Removing animals from the range and feeding them well usually will cause them to recover, but they should not be returned to the range. Other species will cause more severe reactions, and death follows shortly after poisoning. Many species dry during the summer, and ranges can be grazed safely thereafter. Good management, especially avoiding too early grazing, is the best practice to prevent poisoning.

Cicuta. The genus *Cicuta*, known as poison hemlock, water hemlock, and poison parsnip, is among the most deadly of plants. All species are poisonous, and all higher animals are affected. The genus occurs throughout the United States.

Water hemlock is a tall, rank plant characteristic of wet meadows or stream banks. It is a member of the Umbelliferae and has the typical umbel flower head, divided leaves, and tuberous root. Cross partitions in the swollen area between the root and the stem divide the area into a number of flat chambers, which contain a thick brown resin (Fig. 90).

Water hemlock is especially dangerous to cattle, whereas sheep ordinarily do not graze marshy areas where it grows. Cattle, being larger, pull the plants from the soil and consume the highly poisonous tubers. Though the tubers contain more poison than the tops, the entire plant is poisonous in early spring. The tops are seldom dangerous after the plants are half grown; and since the tubers are not readily removed after the soil dries, poisoning after early spring is unusual. Only 2 to 3 oz. of the tubers is necessary to kill a sheep, and ½ lb. will kill a cow. The leaves are less toxic, 3 oz. of the early shoots having been sufficient to kill a sheep, whereas 8 oz. of the unfolded leaves caused death. Of the mature leaf, 10 lb. produced no symptoms. Consumption of 41 lb. of old tops by a cow in a single day produced no symptoms (10). No remedy has proved successful for *Cicuta* poisoning. Death is usually sudden, the animal being found near the source of the poison.

Lupinus. The lupines, or wild beans, are common throughout the mountains and many grasslands of the West. They are recognized by their palmately compound leaves, which usually bear a silky pubescence (Fig. 91). The flowers, of various colors, are typical leguminous flowers and are born in dense clusters. There are many species, most of which are somewhat poisonous, though some are not.

Though poisonous lupines are toxic to all kinds of livestock, only sheep are seriously affected. The lupine is a treacherous plant in that some

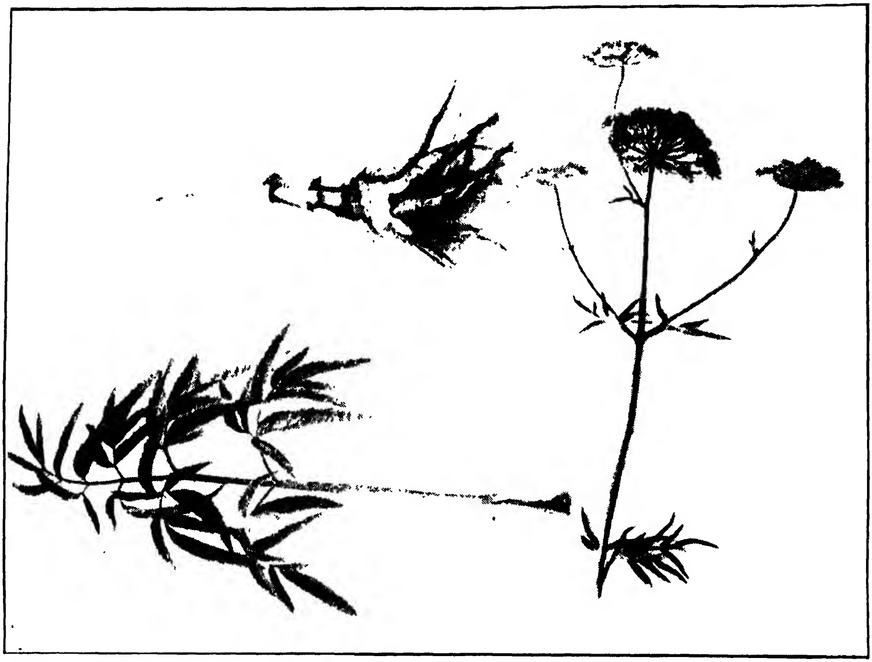

FIG. 90. Western water hemlock (*Cicuta occidentalis*) is characterized by a rootstock which is subdivided into a number of poison-bearing chambers.

species furnish excellent forage under some conditions. Being a legume, it is high in protein, and some are well liked. Tremendous losses, however, have been reported during the fruiting season. The pods and seeds contain more poison than the leaves, though leaves at all ages are poisonous if consumed in quantity. It is difficult to formulate rules for grazing *Lupinus*, for many stockmen consider it an excellent forage. It always should be used with caution, however, for the species are difficult to identify, and most are dangerous at certain seasons. The poison is not cumulative. Under ordinary range grazing, considerable use can be made of it without damage. A sheep can safely consume 1 to 3 lb. of the leaves of most species, though ½ to 1½ lb. of the pods and seeds is likely to

cause death. No method of treatment has proved beneficial, and death is likely to follow consumption of an amount necessary to induce any symptoms. Grazing the plant either before or after the fruits are produced and avoiding turning hungry animals on lupine ranges generally will prevent serious loss.

Asclepias. The genus *Asclepias*, known as milkweed, includes a number of poisonous species. Though the genus is found throughout the West,

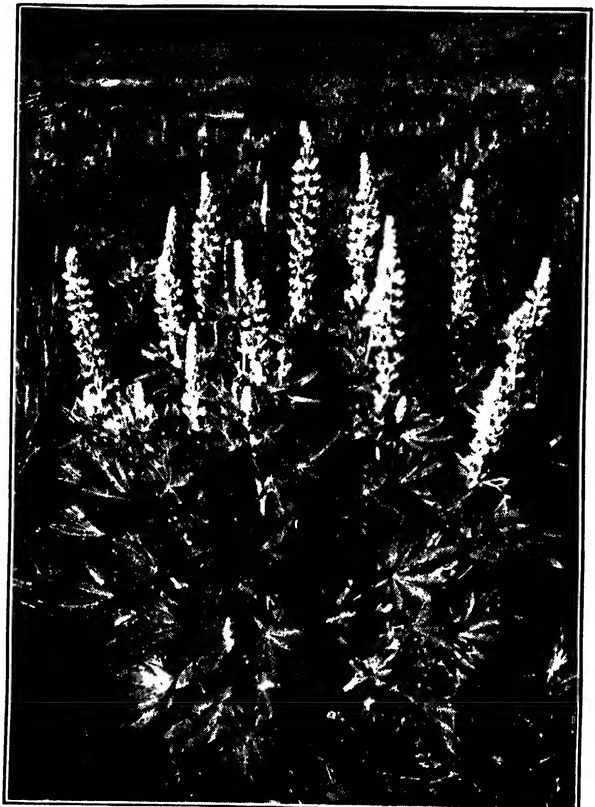

FIG. 91. Lupine (*Lupinus* spp.) is easily identified by its palmately divided leaf and typical leguminous flowers, usually blue.

it is most important in the Southwest, where it causes extensive losses. Most of the poisonous milkweeds are perennials growing from rootstocks; hence, they spread rapidly. The typical milky juice and pods filled with silk-bearing seeds serve to identify them. They are almost universally indicative of range misuse, and animals eat them only as a last resort (Fig. 92).

All kinds of livestock are poisoned by the milkweeds, but only sheep are damaged under ordinary conditions. Cattle consume the plants only

when confined where nothing else is available. The plants are poisonous at all seasons, even when dry; and poisoning takes place in the fall and winter. From ¼ to 5 lb., depending upon the species, is necessary to kill a sheep, and no cure is known.

The Laurels. That group of the Ericaceae family commonly called laurels are a serious menace to sheep on the western coastal ranges. This group includes *Leucothoe davisiae*, *Kalmia microphylla*, *Menziesia ferruginea*, *Rhododendron occidentale*, and *R. albiflorum*. Of this group, *Leucothoe*, or black laurel, is much the most important. Like all the group, it is marked by thick, leathery leaves. The flowers are white and grow in small racemes. *Leucothoe davisiae* causes severe losses among sheep in the northern Sierra Nevada mountains (15). It is extremely toxic, only 1 to 2 oz. being necessary to kill a sheep. The other laurels are less dangerous.

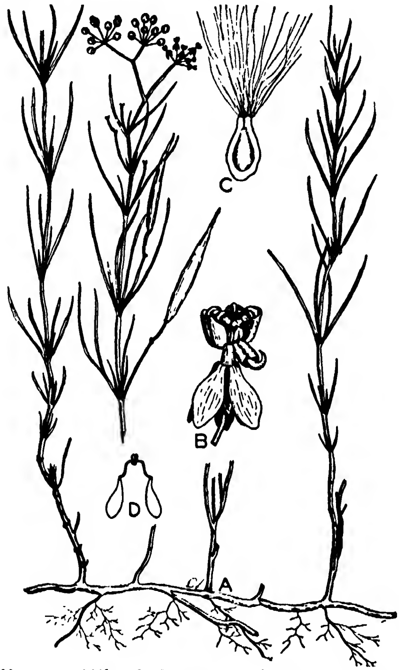

FIG. 92. Whorled milkweed showing (*A*) the plant with underground rootstocks, (*B*) the flower, generally pinkish color, (*C*) the seed tipped with silky hairs, and (*D*) the pollen sacs. (*From Special Report No. 2, Utah Agr. Expt. Sta.*)

No treatment has been successful in laurel poisoning. Prevention is accomplished largely by avoiding the patches. Fortunately, this group is low in palatability, and no animal but the very hungry will touch the plants.

Prunus. The wild cherry, or chokecherry, is common and is known to cause serious losses among sheep. Dense stands of *Prunus* on mountain ranges and hedges growing along roadsides where animals are driven cause losses among both sheep and cattle.

The chokecherry is recognized from its resemblance to the cultivated cherry. The fruits and flowers, however, are smaller and are produced in pendulous racemes. The action of chokecherry poisoning is rapid, the poison, hydrocyanic acid, being so deadly as to allow no opportunity for cure (9). Poisoning is most likely when the plants are wilted or frozen and it is desirable to avoid chokecherry clumps in bedding or shading up. The quantity necessary to kill a sheep may be about ¼ to 1 lb., although this is highly variable. Consumption of water appears to hasten death as with other hydrocyanic acid poisons.

Triglochin. Arrowgrass is a member of Juncaginaceae, resembling a grass in growth. It is found throughout the West in wet and usually alkaline meadows, often partly submerged, and locally along the seacoast. *Triglochin maritima* grows 1 to 2 ft. high and produces spongy leaves resembling a half circle in cross section. The green flowers are produced in dense racemes (Fig. 93).

Arrowgrass is poisonous at all times; even dry plants in hay cause poisoning. Young plants, however, are more poisonous than the mature plants. *Triglochin* poisoning is due to hydrocyanic acid. Usually 2 to 2.5 per cent of the body weight must be consumed to cause death, and animals obtain a lethal quantity only when the plant is very abundant. Like other hydrocyanic acid bearing plants, however, arrowgrass becomes more poisonous when growth rate is retarded by dry soil or freezing weather. Further, it appears to increase in palatability under these conditions. Death follows closely after consumption of the plant, it being one of the most rapid-acting poisons found on the range. Cattle and sheep appear to be poisoned with equal readiness.

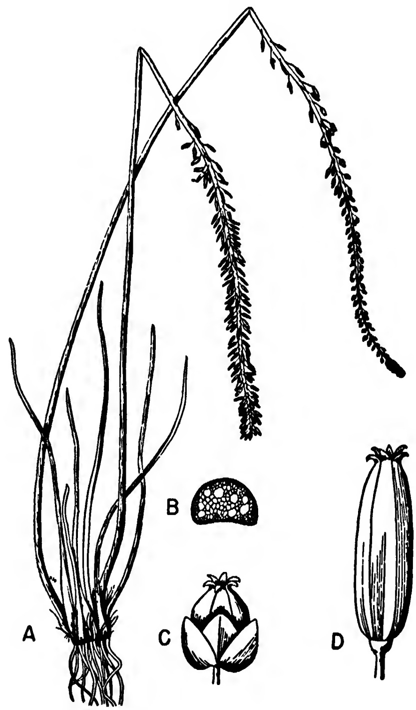

Fig. 93. Arrowgrass (*Triglochin*) showing (*A*) the plant, (*B*) the leaf in cross section, (*C*) the young seed pod, and (*D*) the mature fruit with 6 sections. (*From Special Report No. 2, Utah Agr. Expt. Sta.*)

Heavy salting, careful herding, or fencing those areas where the plant is abundant is probably the best procedure for preventing losses from *Triglochin*, for it seems to be attractive to animals because of its high salt content. Immediately after the first fall frost or after a wet meadow dries up in midsummer are especially dangerous periods.

Halogeton. *Halogeton glomeratus* is an annual member of the Chenopodiaceae family, characterized by reddish stems, and bluish-green sausage-shaped leaves tipped by a single hair. In fall it is completely covered by bract-bearing fruits (Fig. 94). The plant is characteristic of salty, bare, and disturbed soils of the intermountain desert ranges, where locally it is extremely abundant.

The plant is poisonous throughout life, but fortunately it is so un-

palatable that only under unusual circumstances will animals eat enough to endanger them. Cattle are almost never poisoned. The poison is an oxalate, and ordinarily ½ to 1½ lb. of the plant will kill a sheep (6). A poisoned animal seldom recovers and no cure is known.

Keeping animals well fed and avoiding trails and bed grounds densely populated by halogeton will practically eliminate danger. Feeding supple-

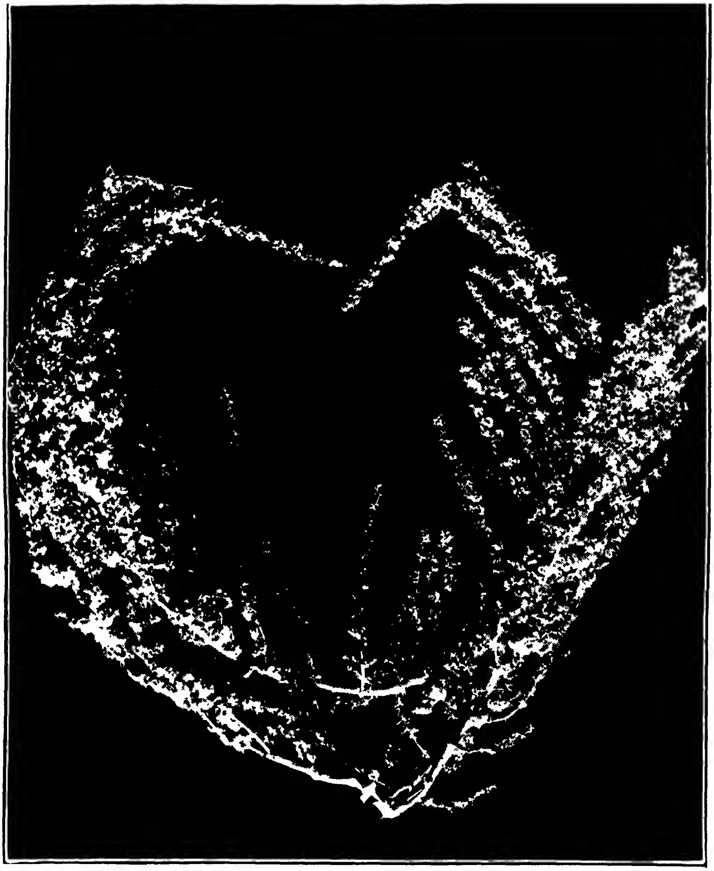

FIG. 91. Halogeton seeds (on facing page) about ¼ inch from wing tip to wing tip, and the seed-covered Halogeton plant (above) as it appears in fall.

ments high in calcium will reduce susceptibility to poisoning. Death occurs about 6 to 8 hours after consuming the plant. Post-mortem examination shows blood hemorrhage in the lungs and calcium oxalate crystals in the kidney tubules. Good range management to reduce halogeton quantity plus proper herding methods appear to offer best solutions to the halogeton problem.

Bitterweed. *Actinea odorata* is an annual plant characteristic of disturbed range lands of west Texas and westward through the southern desert ranges. The plant has been important only since about 1922 when heavy stocking by sheep became common (24). It is a member of the Compositae family, 6 to 18 inches high, bearing numerous small yellow-rayed flowers and leaves subdivided into long linear segments.

FIG. 94. (*Continued*)

Sheep losses of 10 to 25 per cent from bitterweed were noted in Texas (24), especially on overgrazed and droughty ranges. Small amounts (0.1 per cent of body weight) consumed for long periods or larger amounts (0.3 per cent of body weight) consumed in a single day will produce weakness and depression. Prolonged feeding or consumption of larger amounts will cause death. There is a definite correlation between the amount consumed and appearance of symptoms, regardless of time involved. This clearly suggests that the poison is cumulative.

Spring is the season of heavy loss. Grazing only after other and palatable feeds are available in the spring and avoiding roads, trails, bed grounds, and overused water holes will reduce losses. Good range management appears to be the practical solution to the problem since this species is readily crowded out by perennials; and being unpalatable, animals ordinarily will not consume dangerous amounts if other feed is available.

Hypericum. Saint Johnswort, goatweed, or Klamath weed (*Hypericum perforatum*), is an unpalatable introduced perennial weed spreading rapidly, especially in the northwestern United States. Unlike most

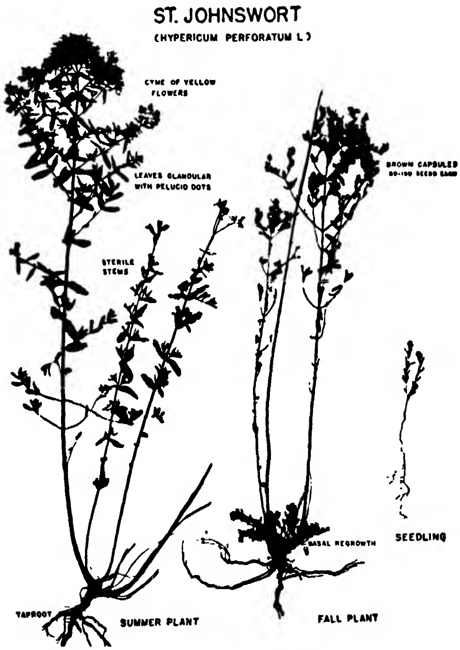

FIG. 95. Saint Johnswort. (*Photograph by E. W. Tisdale.*)

invaders, this plant, by means of underground rhizomes, crowds out valuable forage plants and reduces grazing capacity (12). It is a 1- to 3-ft.-high plant, with numerous yellow flowers (Fig. 95). The leaves are small and are pitted by characteristic small glands on the undersurface.

Saint Johnswort is only slightly poisonous to animals, and deaths are few. The poison in the leaf glands, however, causes severe skin irritation resulting from photosensitivity following consumption or direct contact by the skin. Loss in weight and general poor health result. Animals with white skin are affected. Cattle are more susceptible than sheep. Symptoms result from consumption of 1 per cent of body weight, and death results from consumption of 5 per cent. No cure is known.

Complete eradication of Saint Johnswort seems impossible once it is established. Costly mechanical and chemical controls are not promising; however, recent introduction of a beetle (*Chrysolina*) which feeds exclusively on the plant gives real hope of holding Saint Johnswort under control.

Selenium Poisoning. Selenium is a poisonous mineral absorbed by certain plant species, making the plant poisonous to livestock. Originally, the effect upon livestock was attributed to bad water (26). A chronic form is known as alkali disease and an acute form as blind staggers. The former comes from continued consumption of a ration containing low concentrations of selenium (5 to 40 p.p.m.), whereas the latter comes from consuming plants containing hundreds or thousands of parts per million (19). Animals may die or may merely be stunted in growth. Sloughing of hair and hoofs is common, and abnormal development of hoofs is characteristic. Dullness and lack of vigor are followed by nervousness and staggering, with impaired vision. All kinds of livestock are susceptible.

The extent of selenium-bearing soils in the United States is not well known. Shales of many western states contain various amounts. Wyoming and South Dakota appear to be most affected, though selenium has been

TABLE 44. VARIATIONS IN SELENIUM CONTENT OF SOIL AT DIFFERENT DEPTHS AND OF PLANTS GROWING IN THE AREA

Data from Beath et al. (2)

Depth of Soil, inches	Selenium Content of Soil, p.p.m.
0–12	20.4
12–24	15.8
24–36	11.7
36–48	8.4
48–60	7.8

Species of Plants Growing on Above Area	Selenium Content of Plants, p.p.m.
Grasses, mixed	47
Astragalus bisulcatus	2,590
Astragalus pectinatus	860
Atriplex nuttallii	135
Aster adscendens	161
Oonopsis condensata	3,250
Stanleya pinnata	1,252

reported from soils and vegetation in Idaho, Montana, North Dakota, Utah, Colorado, New Mexico, Arizona, Oklahoma, Kansas, and Nebraska (19, 28). Cretaceous shales of the plains area are particularly productive of selenium.

Although the concentrations found in most soils are low, these may produce highly toxic vegetation. A minimum of 0.5 p.p.m. must be exceeded in the plant before it becomes dangerous (4). Species vary greatly in the absorption of selenium (Table 44).

TABLE 45. PLANTS REGARDED AS BEING INDICATIVE OF THE PRESENCE OF SELENIUM AND OTHERS USUALLY BEARING CONSIDERABLE AMOUNTS IN THEIR TISSUES
After Beath et al. (2)

Major Importance (Indicative of Selenium Soils)	Secondary Importance (Not Confined to Selenium Soils)
Astragalus bisulcatus	*Aster adscendens*
Astragalus confertiflorus	*Aster commuttatus*
Astragalus eastwoodae	*Aster ericoides*
Astragalus flaviflorus	*Aster glaucus*
Astragalus flavius	*Atriplex canescens*
Astragalus grayi	*Atriplex nuttallii*
Astragalus haydenianus	*Grindelia* spp.
Astragalus limatus	*Gutierrezia* spp.
Astragalus oocalycis	*Machaeranthera ramosa*
Astragalus pattersonii	*Mentzelia decapetala*
Astragalus pectinatus	*Sideranthus grindelioides*
Astragalus praelongus	
Astragalus preussii	
Astragalus preussii var. *latus*	
Astragalus racemosus	
Astragalus scobinatulus	
Astragalus toanus	
Astragalus urceolatus	
Oonopsis argillacea	
Oonopsis condensata	
Oonopsis engelmannii	
Oonopsis foliosa	
Stanleya bipinnata	
Stanleya integrifolia	
Stanleya pinnata	
Stanleya tomentosa	
Stanleya viridiflora	
Xylorrhiza glabriuscula	
Xylorrhiza parryi	
Xylorrhiza venusta	
Xylorrhiza villosa	

A number of plants have been found to be indicative of the presence of selenium in the soil. Other plants have large amounts of selenium when growing upon selenium soils but may not be confined to such soils (Table 45). Still others obtain appreciable amounts of selenium when growing in areas where other species have accumulated the element and, upon decomposition, have deposited it in a more readily available form. This

seems to account for the occurrence of selenium in cultivated crops and grasses.

Fortunately, selenium seems to impart to vegetation undesirable properties, rendering it unattractive to animals. Workers in South Dakota have found rats to be able to detect selenium in grains and to reject poison-bearing grain. It is reported that range animals will avoid selenium-bearing plants; hence, if they are allowed sufficient range, they

FIG. 96. A Holstein cow suffering from photosensitivity and showing how white skin is affected and black is not.

will not be in great danger (4). Selenium-bearing plants have a most characteristic odor, faintly like garlic, which, once smelled, will always be remembered. This may tend to repel animals.

Drenching animals in the early stages of poisoning with calcium lactate has been found to cure them. One-third ounce three times per week is sufficient for a 600- to 800-lb. cow (14). Five to twenty-five parts per million of arsenic in the salt improves gains and reduces symptoms of selenium poisoning on the range (20). A high level of protein in the diet has been shown definitely to reduce damage from selenium (27).

Photosensitization. A number of western plants, when eaten, produce sensitivity to light that results, especially in white animals, in severe dermatitis. The marked symptoms are blistered or sunburned skin which will later slough off (Fig. 96), and swelling, especially about the head, which, in extreme cases, may be followed by serum discharge and sores. This results in the typical appearance to which is applied the name bighead or swellhead (Fig. 97). Extreme lethargy and drooping of the ears are characteristic. Internally, there is obstruction of the bile duct, with resultant deterioration of the liver and kidneys. Death may not

FIG. 97. A sheep showing typical symptoms of bighead—a photosensitization resulting in swelling of the head, extreme lethargy, and drooping of the ears.

result from the disease, the outcome depending upon the plant species involved and the severity of the poisoning.

In the intermountain area, horsebrush (*Tetradymia glabrata* and *T. canescens*) are known to cause large losses (Fig. 98). In the Southwest, agave (*Agave lecheguilla*) and the less important sachuiste (*Nolina texana*) have been found troublesome. Saint Johnswort (*Hypericum perforatum*) causes similar results, although the disease is not so severe. Buckwheat (*Fagopyrum esculentum*), smartweed (*Polygonum persicaria*), and Sudan grass (*Sorghum vulgare* var. *sudanensis*) produce symptoms. Similar diseases have been associated with plants in other countries, among them *Tribulus terrestris* in South Africa and *Panicum effusum, Trifolium hybridum*, and *Medicago denticulata* in Australia.

Most of these plants are of inferior forage value, and poisoning is of minor importance under proper grazing. Bighead commonly is con-

tracted during periods when sheep are being trailed. Although painting the skin of animals with dark dyes prevents the edematous condition, this is neither a practical nor a complete remedy. The same may be said of keeping the animals out of strong sunlight, although such action minimizes the effects. Some plants will cause dermatitis by contact alone and do not need to be consumed.

FIG. 98. Spineless horsebrush (*Tetradymia canescens*), believed to be one cause of bighead of sheep, as shown in Fig. 97.

MECHANICALLY INJURIOUS PLANTS

Many western plants are injurious to animals in a mechanical way. Plants having sharp spines, stipes, awns, and seed coats may puncture the skin; thus screwworms and fungi, such as those causing actinomycosis or lumpy jaw, are enabled to enter. Others become embedded in the tongue, gums, and eyes of range animals. Death seldom results, but affected animals are likely to be in poor condition.

Perhaps the most serious mechanical injury is caused by squirreltail (*Hordeum jubatum*), which is characterized by long awns containing hundreds of minute spines on their margins. Plants that cause similar mechanical injuries (8, 21) include threeawn grass (*Aristida* spp.), wild oat (*Avena fatua*), foxtail chess (*Bromus rubens*), rip-gut grass (*B. rigidus*),

downy bromegrass (*B. tectorum*), medusa rye (*Elymus caput-medusae*), porcupinegrass or needlegrass (*Stipa* spp.), sandbur (*Cenchrus tribuloides*), sticktights (*Bidens* spp.), puncture vine (*Tribulus terrestris*), cocklebur (*Xanthium* spp.), and many species of cactus.

Other plants, including cactus, mullein (*Verbascum*), soapweed (*Yucca*), oak (*Quercus*), and bitterweed (*Actinea*), contain fibers, hairs, rubber, or other materials that ball up and cause irritation and sometimes compaction when eaten in large quantities (8).

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CHAPTER 11

NUTRITION IN RELATION TO RANGE MANAGEMENT

A major objective of range management is production of livestock; and because ranch income is derived from livestock, production takes on great significance. Livestock production is closely correlated with efficiency of the forage in supplying animal nutriment. Much remains unknown in the field of range nutrition, for the science is yet in the formative stage. Of great importance, however, is the study of the requirements for animal maintenance, growth, and reproduction and the ability of range forage to meet these demands.

GENERAL NUTRITIONAL REQUIREMENTS

The first requirement of a mature animal is food to maintain its internal body processes and support normal muscular activity. This minimum is known as the *maintenance requirement*. The forage constituents necessary to meet these demands include proteins for repairing worn-out tissue and building new; fats and carbohydrates for the production of heat and energy; minerals for bone building, general body functions, and satisfying body secretions; and vitamins, which play a multiple role in the normal body processes.

Numerous minerals are essential for animal life; but most of these are normally present in adequate amounts, and only those likely to be deficient are of immediate importance to the range manager. The minerals of most concern to range and pasture management are: phosphorus, calcium, iron, copper, cobalt, sodium, chlorine, iodine, potassium, and magnesium.

Calcium and phosphorus are essential for bone growth and numerous other body functions. In many animals a rather specific ratio between calcium and phosphorus is of great importance, but for cattle and sheep this seems to be a secondary consideration so long as the minimum requirements for both calcium and phosphorus are met and animals receive adequate vitamin D (8). There are several food constituents such as fatty acids, vitamins, and minerals that affect the absorption

and utilization of calcium and phosphorus. Of these, vitamin D is of great importance and must be present for normal bone growth.

There are many terms used to designate the nutritional failures of calcium and phosphorus, but generally they can be limited to rickets for younger animals and osteomalacia for adult animals.

Chlorine is a constituent of certain body secretions; its absence causes breakdown in health, failure of appetite, and loss of weight. Sodium is also necessary to the animal body, and a lack of it for extended periods of time causes a loss in weight, a decrease in milk supply by the female, and other physiological distrubances. Iodine is deficient in certain areas, and its absence is characterized by abnormalities in reproduction, impaired growth, and goiter.

Only along the coastal areas, where the soils are sandy and rainfall is heavy, have copper, cobalt, and iron deficiencies been found to exist. In Florida, nutritional anemia was found in numerous areas and described as *salt sick* (3). Iron deficiency was first believed to be the cause of this sickness, but more recently it has been shown to be a complex deficiency involving copper, cobalt, and iron. A deficiency of either cobalt or copper produces nutritional anemia by interfering with the use of iron in the formation of hemoglobin.

Complex mineral balances involving divalent elements, such as calcium and magnesium, and monovalent elements, such as potassium and sodium, are believed causes of such sickness as grass tetany, milk fever, and wheat poisoning. Improper proportions of these minerals may produce an improper balance in the extracellular fluids and within the cells and result in nervous or glandular disturbances.

Of the several vitamins, only vitamins A and D appear to be of importance to herbivorous animals (31, 45). Vitamin A is important in the growth of young animals, in preventing infections and night blindness, and in maintaining vigor and normal reproduction in adults. It is formed from carotene, found in fresh green feed, and is likely to be deficient only where animals are grazed on dry feeds. When the diet is high in carotene, vitamin A is stored in the body, primarily in the liver and fat. Therefore livestock on dry leached forage may not show vitamin A deficiency symptoms for 60 to 180 days. The period of time before deficiencies appear will depend upon the age of the animal and general feed conditions prior to being on dry forage. Good green alfalfa hay that has not been in storage long is considered a good source of vitamin A for a livestock supplement. Storage, however, allows the carotene in the hay to become destroyed through oxidation, and such hay would not be a good source of vitamin A, even though the hay still appeared green in color. Since vitamin D is obtained from sunlight, it is unlikely to be deficient under range conditions.

Vitamin E or wheat-germ oil has frequently been used in the treatment of noninfectious barrenness in range livestock, but studies in the United States have not established satisfactorily that vitamin E improves the potency of the male or corrects difficult breeding in females (64).

NUTRITIONAL REQUIREMENTS OF LIVESTOCK

Complete agreement has not been reached as to the standard allowance of the various nutrients for livestock. However, the National Research Council (46, 47) has recommended allowances for both beef cattle and sheep under farm-lot conditions. The quantitative maintenance requirements of range animals have not been determined, but the requirements in feed lots are approximately known.

TABLE 46. RECOMMENDED NUTRIENT ALLOWANCES FOR WINTERING MATURE BEEF CATTLE AND SHEEP DURING PREGNANCY CALCULATED ON THE BASIS OF 90 PER CENT DRY MATTER
Data from National Research Council (46, 47)

Type of livestock	Daily feed intake, pounds	Digestible protein, per cent	Total digestible nutrients, per cent	Calcium, per cent	Phosphorus, per cent	Carotene, parts per million
Beef cattle..	20.0	4.5	50	0.20	0.18	6.7
Sheep.......	3.8	5.0	50	0.20	0.16	6.7

Recommended allowances for farm-lot animals are frequently higher than necessary, since authors have provided for a wide margin of safety because of variations among feeds and among breeds, and for other contingencies that might occur. For example, the National Research Council allowance for carotene (Table 46) is generally considered to be about four times the accepted minimum level for optimum growth. Therefore, adding supplements to range forage in sufficient quantities to meet the standard allowance suggested for farm-lot animals may not be necessary. However, the energy requirements of range animals are somewhat higher than those in farm lots, especially in winter, because they travel in search of food and must maintain body temperatures without the aid of shelter. These facts suggest that economy may be achieved by decreasing the protein allowances and supplementing with cheaper carbohydrate feeds which provide the energy needed for active foraging on the range. The kind and amount of supplement always should depend upon the type and amount of range forage available, the cost of supplements, and the expected return from sales.

Calculating Requirements. Although it is well accepted that body size is not a direct index to forage requirements, most early feeding standards were based upon weights. Actually it appears that body surface may be more closely related to feed requirements, especially for basic maintenance needs. Body surface varies with the two-thirds power of the weight of the animal. Attempts to establish feed requirements on the basis of this relationship indicated that basal metabolism varied as the 0.734 power of body weight. Other investigators have reported higher values, so that at present the exponent is believed to be somewhere nearer three-fourths.

The variable results secured suggest that basal metabolism may not be the best basis for calculating feed requirements. Needs for growth and fattening may not relate to surface area which may account for the failure to secure results in proportion to this factor. Practically, it may suffice to use weight as the basis for calculations, if it be remembered that young animals, i.e., smaller animals, have greater needs than mature animals which have no growth requirements to meet.

Measuring Forage Value. In appraising the value of range forage, the most important factors to consider are its productive energy and its content of digestible protein, phosphorus, and carotene (vitamin A). Deficiency in these may result from low quality in the forage or insufficient forage.

For evaluating rations or diets of animals on winter range where weather conditions are severe, *metabolizable energy* values are more suitable indexes to energy-supplying qualities than the commonly used *total digestible nutrient* content of the forage. This is of special concern in appraising the energy values of range shrubs which are high in essential oils. Species high in essential oils have high total digestible nutrient values, but may be extremely low in metabolizable energy. The presence of essential oils results in high ether-extract (fat) values, but these oils are lost largely through the urine; therefore, they do not yield energy as indicated by total digestible nutrient determinations (14).

If a 130-lb. ewe during gestation consumes an average of 3.8 lb. of air-dry forage daily, then the ingested material should contain from 5,758 to 7,150 calories of metabolizable energy per pound of air-dry matter to meet the energy requirements (14). These figures do not make allowance for excessive travel in search of food.

CATTLE

Complete agreement has not been reached as to the amount of air-dry forage required to maintain cattle, but, depending upon quality, it appears to be near 20 lb. per day per mature animal. About 20 lb. of range forage per day maintains a 1,000-lb. cow on the Edwards Plateau

of Texas (75). Watkins calculates 19.5 lb. daily of dry range feed are required for maintaining 887-lb. breeding cows in New Mexico (66). In California, cattle consume about 3 lb. of dry matter per 100 lb. live weight daily, varying from 2.00 to 3.25 lb. (28).

Maintenance. When an animal receives adequate carbohydrates and fats, the amount of protein required is reduced to a minimum. Young growing animals require more protein than do mature animals (63). Good-quality roughage containing 7 to 8 per cent total protein is satisfactory for mature cattle but not for growing animals (28). A protein content in excess of 16 to 18 per cent is of no advantage (39).

Little is known of the mineral requirements for maintenance. Generally, results below normal will be produced when the daily phosphorus intake per head of mature cattle falls below 10 grams and calcium below 20 grams, or if the calcium content of the range forage is below 0.25 per cent and the phosphorus content below 0.12 per cent (66). Pregnant or nursing cows are believed to require about 0.20 per cent of phosphorus in the feed (28).

The minimum daily vitamin A requirement for a mature beef cow is 7,000 I.U. or about 1.65 parts of carotene per million parts of total feed intake.

Growth and Fattening. Only after the requirements for maintenance are met can food be utilized for growth and fattening, an increase of energy-producing constituents and protein being required for growth and fattening (Tables 47, 48). Ten to twelve per cent total protein in the ration is recommended for rapid growth (28).

TABLE 47. DAILY TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS FOR GROWING AND FATTENING BEEF CALVES

Data from Morrison (45)

Live weight, pounds	Growing beef cattle fed liberally for rapid growth, pounds	Fattening yearling cattle, pounds	Fattening two-year-olds, pounds
300	5.1–6.2		
400	6.2–7.2		
500	7.2–8.4		
600	8.1–9.3	10.7–12.3	
700	8.9–10.2	12.7–14.3	
800	9.5–10.9	14.1–15.9	14.1–15.9
900	10.1–11.5	15.4–17.2	14.6–17.4
1,000	10.6–12.0	16.0–18.0	16.5–18.5

The recommended phosphorus allowance for fattening beef steers is about 0.17 per cent phosphorus in the ration (46). Steers on a ration low

in phosphorus require more feed to make a pound of gain than with adequate phosphorus, indicating that phosphorus is essential for economical utilization of feed. The minimum phosphorus requirement for growing cattle is usually estimated at 0.20 per cent of the ration (28, 29),

TABLE 48. FEED REQUIREMENTS FOR FATTENING BEEF CATTLE OF VARIOUS AGES PER 100 LB. LIVE WEIGHT PER DAY

Data from Stiles and Morrison (58)

Stock class	Digestible crude protein, pounds	Total digestible nutrients, pounds	Dry matter, pounds	Nutritive ratio
Calves	0.225–0.275	1.74–1.88	2.40–2.56	1:6.0–7.3
Yearlings	0.198–0.244	1.68–1.80	2.22–2.42	1:6.4–7.8
Two-year-olds	0.170–0.212	1.62–1.72	2.04–2.28	1:7.7–9.0

TABLE 49. ESTIMATED DAILY REQUIREMENT OF GROWING AND FATTENING BEEF STEERS

Data from Mitchell and McClure (44)

Body weight, pounds	Growing steers			Fattening steers		
	Dry matter, pounds	Necessary phosphorus in ration, per cent	Necessary calcium in ration, per cent	Dry matter, pounds	Necessary phosphorus in ration, per cent	Necessary calcium in ration, per cent
300	7.83	0.35	0.43	11.46	0.34	0.48
400	8.80	0.31	0.35	12.35	0.31	0.40
500	10.01	0.27	0.29	13.65	0.27	0.33
600	10.72	0.26	0.25	14.33	0.25	0.29
700	11.66	0.23	0.21	15.38	0.23	0.25
800	12.44	0.21	0.18	16.20	0.21	0.22
900	13.16	0.20	0.16	16.94	0.20	0.20
1,000	14.11	0.19	0.14	17.98	0.18	0.17
1,100	14.95	0.18	0.12	18.89	0.17	0.15
1,200	15.77	0.17	0.11	19.77	0.16	0.13

although much lower values have been suggested. Mitchell and McClure have suggested about 0.35 per cent phosphorus in the feed for a 300-lb. growing steer to about 0.17 per cent for a 1,200-lb. animal (Table 49). The recommendations for calcium range from 0.43 per cent in the feed to 0.11 per cent. Young animals, even though they are smaller, may require more phosphorus and calcium than mature animals (61).

Reproduction. With notably few exceptions, the dietary requirements for reproduction, qualitatively and quantitatively, do not exceed the requirements for maintaining mature animals in good health (63). It is important, however, that cows, to produce vigorous offspring, receive sufficient proteins, minerals, and vitamins. Pregnant beef cows of 800 to 1,000 lb. weight may be wintered on 14.2 to 20.0 lb. of dry matter daily containing 4.5 per cent digestible protein, 50 per cent total digestible nutrients, 0.18 per cent phosphorus, and 1.6 to 2 p.p.m. carotene. During the last 3 months of gestation, the fetus makes rapid growth, and the protein requirement may rise to as high as 40 per cent above maintenance (63). Throughout pregnancy, it probably averages about 17 per cent higher, necessitating a narrower nutritive ratio as the gestation period progresses.

The calcium and phosphorus requirements during pregnancy are little above maintenance requirements until the last 2 months. Mitchell and McClure (44) found that, for a cow weighing 1,000 lb., the calcium requirement rose to 11.7 grams daily, or 0.19 per cent of the feed, during the eighth month of pregnancy, and to 19.5 grams, or about 0.42 per cent of the feed, during the last month. Phosphorus requirement rose to 11.4 grams daily, or 0.25 per cent of the feed, during the eighth month, and to 14.3 grams, or 0.35 per cent of the feed, during the last month. Poor reproduction in California was attributed, in part, to deficiencies of calcium and phosphorus in range forage associated with a low protein intake (30). The same has been found to be true in Africa (61). Numerous experiments in the United States have shown the value to reproduction of supplementing calcium and phosphorus on deficient ranges (4, 5, 33, 48, 50).

Iodine, in minute quantities, is essential for reproduction, its absence causing the birth of weak or dead calves with enlarged thyroid glands. Several of the western states have iodine deficiency in certain areas (63). A content of 0.02 per cent of potassium iodide in the salt will prevent symptoms of deficiency (28, 38).

Vitamin A is essential for normal reproduction. Daily levels of 6.7 to 8.4 micrograms per kilogram of body weight seem to be sufficient for cattle (27). If cattle have normal storage of vitamin A in the body, diets containing as much as 2 p.p.m. would meet the minimum requirements (46).

SHEEP

Roughage in large amounts can be used by sheep for maintenance and fattening. Their ability to consume numerous forb and browse plants makes them particularly adapted to grazing on western ranges.

Maintenance. As with range cattle, the maintenance requirements of range sheep have been studied but little. However, farm-lot investigations show that the requirement for maintenance of a 100-lb. sheep is about 3 lb. of dry matter daily. The nutrient requirement per day for wintering pregnant ewes up to 6 weeks before lambing is only slightly above the maintenance requirement (47). Sheep display a greater appetite on grass than on other winter diets, the consumption varying from 3.21 to 6.04 lb. of dry matter daily for mature sheep (72). Stapledon and Jones (57) found the amount of herbage eaten daily to be 9.8 to 24.2 lb. when green or 2.6 to 3.4 lb. when dry for sheep of various weights, an average of about 3.0 lb. being generally sufficient. Some requirements of sheep at various weights are shown in Table 50.

TABLE 50. DRY-MATTER MAINTENANCE REQUIREMENTS FOR SHEEP OF DIFFERENT WEIGHTS

Data from Woodman et al. (71)

Live Weight, Pounds	Dry Matter, Pounds per Day
60	2.07
90	2.73
100	2.91
110	3.10
120	3.27
130	3.46
140	3.64
150	3.83
160	4.00
170	4.13
180	4.26
190	4.37
200	4.50

DuToit *et al.* (19) found mature ewes to require only 1.53 grams of phosphorus daily which is only about two-thirds the quantity recommended by the National Research Council (47).

Iodine may need to be fed to ewes in goiter areas, 1/20 grain of potassium iodide per ewe daily being sufficient (63). Iodine also can be added to the ration as iodized salt.

Of the vitamins, vitamin A is the only one likely to be lacking under range conditions, and then only when the forage is dormant and dry. The requirement for vitamin A is about the same per unit of body weight as for cattle (63). The minimum daily requirement is about 2 to 6 mg. of carotene or a ration containing about 1.6 to 5 p.p.m. carotene. The minimum requirements for vitamin A are about 975 I.U. for a mature sheep per day.

Growth and Fattening. For growth, 0.22 lb. of digestible protein daily for a 100-lb. sheep of a mutton breed is considered desirable (1). The average daily requirement of phosphorus for ewe lambs of 50 to 110 lb. weight is about 1.34 grams and, for rams, 1.48 grams. The average daily calcium requirement is 1.40 grams for ewe lambs and 1.59 grams for ram lambs (44). Rations containing from 0.13 to 0.15 per cent calcium and 0.14 per cent phosphorus should, under the best conditions of mineral utilization, be adequate for normal growth (Table 51). Fattening lambs require about 2.5 grams of phosphorus daily per 100 lb. of live weight for efficient and rapid gains (7).

TABLE 51. ESTIMATED DAILY REQUIREMENTS OF EWES OF VARIOUS WEIGHT CLASSES

Data from Mitchell and McClure (44)

Body weight, pounds	Dry matter, pounds	Necessary calcium in ration, per cent	Necessary phosphorus in ration, per cent
50	2.40	0.13	0.11
70	2.13	0.15	0.14
90	2.21	0.14	0.13
110	2.30	0.13	0.14
130	2.34	0.11	0.14

Wool Production. It is common knowledge that the plane of nutrition has a marked effect upon wool production by sheep. Adverse conditions, such as sickness, undue exposure, or a decided lack of feed, will decrease the yield of wool and produce smaller weaker fibers (45). Sheep on a fattening ration grow more wool that is longer in staple, superior in crimp, and stronger than the wool produced on submaintenance rations (70). Lambs fed a liberal ration may produce more than twice as much scoured wool as those on rations below maintenance (69). Studies (20, 21) show that the fleeces of ewes wintered under farm conditions on a high plane of nutrition produced a heavier fleece with a smaller shrinkage and longer staple compared to ewes wintered on desert ranges. Range ewe lambs, farm-fed during their first winter, produced heavier fleeces with a longer staple than those wintered on the range. All experimental evidence points toward greater wool production when sheep are on a high plane of nutrition, and this emphasizes the need for proper grazing practices, permitting the production of sufficient forage to meet the needs of the animal.

Reproduction. Flushing of ewes is the practice of extra feeding prior to and during the breeding period. A properly flushed animal makes a body-weight gain of 7 to 10 lb. (37). It is generally believed that the increase of feed has physiological effects upon the animals that result in

earlier breeding, a higher lamb crop, and a more uniform season of lambing (16). Experimental work, however, does not altogether support this; though many experiments show an increased lamb crop (37), there is little evidence to substantiate claims for earlier lambs or a more uniform season. Serious doubt exists as to whether the slight increases in lamb yield can justify the cost of the grain necessary to produce the increase. Despite many unfavorable results in ewe flushing, the practice is widespread among range sheep producers and is generally subscribed to by technical authorities. Experimental work at Miles City, Mont. (54), and elsewhere (63) showed good fresh range to be as valuable as grain supplement in bringing ewes to a flushed condition. This indicates the importance of special breeding pastures of above-average forage condition and the value of good range in animal production.

Lactating ewes require somewhat higher nutritional levels than they did during the period of gestation. The levels of protein, minerals, vitamins, and energy-supplying substances all need to be increased after lambing for proper nutrition (47). Studies in North Dakota (35) and Montana (65) show that present recommendations for protein allowances are considerably higher than necessary for pregnant ewes.

NUTRITIONAL VALUE OF RANGE FORAGE

Information on the feeding value, chemical composition, and digestibility of range forage is inadequate or entirely lacking. Almost nothing is known of the nutritive value of these plants as influenced by species, climate, stage of growth, type of soil, and other important factors. Only a few studies have been conducted on the digestibility of range forage. Much must be learned about these problems before man's knowledge of animal nutrition on western ranges is adequate for the most intelligent management.

Analytical studies of the various constituents, particularly inorganic elements, reveal that much confusion exists. The inconsistencies, even as to general trends in the mineral constituents and organic contents, leave few definite conclusions. That there is a high protein content and low fiber and nitrogen-free extract in the very early growth stages, followed by a gradual decline in the former and increase in the latter two, with the advance of the season, has been established (23).

Probably much of the mineral deficiency of range forage results, actually, from a deficiency of total feed intake. There are many areas, however, where mineral deficiency is positive and becomes a range problem of major importance, especially during certain seasons of the year.

Total phosphorus is a good indicator of the nutritive value of the plant, because phosphorus and sulfur, phosphorus and protein, and phosphorus

and crude fat vary directly, whereas phosphorus and crude fiber and phosphorus and total ash vary inversely (24). In southern Texas (60) low protein content of forage is associated with low phosphorus content. Furthermore, a deficiency of one complicates a deficiency of the other.

Effects of Season upon Forage Value. With advancing maturity of plants, crude protein and phosphorus decrease and crude fiber, lignin, cellulose, and other carbohydrates increase (11, 12, 13, 23). Seasonal changes are affected by both the changes in the stem-leaf ratio and actual changes in the composition within each plant part. Browse plants generally show less seasonal fluctuation than grasses.

Some species on semidesert lands in the Great Basin area are good forage even during the nongrowing season. The chemical content of most plants on salt-desert winter ranges changes little during the grazing season; however, chemical changes in summer range plants, resulting from advanced growth stages, are greater than those arising from any other factor (12, 13). See also page 320.

Forage of certain California ranges varies from the composition of a protein-rich concentrate during the early vegetative stages to that of a poor roughage when dry (32). McCall (41) concludes that the stage of maturity is most important in its influence upon Idaho fescue (*Festuca idahoensis*). Protein was approximately six times as high in young grass as in the grass 4 months later. Crude fiber varied inversely with protein. Total ash was lowest in new leaves, increased with growth and leveled off with maturity. Phosphorus was higher in young grass than calcium but declined faster especially after maturity, at which time the calcium content leveled off.

In New Mexico, adequate quantities of weathered mesa dropseed (*Sporobolus flexuosus*) and about 1 lb. of cottonseed cake daily will supply a range cow a virtually balanced ration, with the possible exceptions of small amounts of minerals and vitamins (67). In Arizona (55), moisture, crude protein, and phosphorus in young plants are high, but all decrease toward maturity. Crude protein and phosphorus run parallel, being high during the summer rainy season, low in the fall, and high again following winter rains (56). Calcium content was high during early growth, low during the dormant period, and increased rapidly following the rainy season.

Plants of the same species in the same soil type and climate vary markedly in mineral and protein content. Phosphorus, protein, chlorine, sodium, and potassium in grasses diminish rapidly as the stage of growth advances to maturity. Phosphorus is generally low after growth advances beyond 1 month (17, 18).

The vitamin A value of range forages is of considerable importance, especially as it influences reproduction in livestock. Several investigators

have studied carotene content in plants (73, 74) and found the green forage to be exceedingly high. All pasture plants have a relatively high carotene content during early summer, the content decreasing markedly in midsummer and increasing after fall rains when new growth is apparent (2). The carotene content of blue grama (*Bouteloua gracilis*) is extremely high in August, decreasing to about one-half in September, and to about one one-hundredth in November when it becomes dry (53). Studies (68) on the monthly variation in carotene content of two New Mexico range grasses, mesa dropseed (*Sporobolus flexuosus*) and black grama (*Bouteloua eriopoda*) showed that both grasses were moderately high during the growing season. The dropseed lost all its carotene soon after the end of the growing season, but the grama maintained, throughout the winter, an amount ample to satisfy the vitamin A requirements of range cattle.

Leaching. Much of the change in composition of forage with advancing maturity is caused by leaching of the soluble constituents by rain. California studies (26) indicated that calcium is not affected greatly but showed phosphorus to be distinctly lowered. The calcium to phosphorus ratio, therefore, is widened by leaching. Nitrogen-free extract material decreased with leaching, most of the loss being easily digested sugars, which doubtless influence the readiness with which the forage is consumed. In the same region, as the protein of bur clover (*Medicago hispida*) was leached, an increasingly wide nutritive ratio resulted (25). Watkins (66) considers both calcium and phosphorus to be leached by rain from mature range grasses.

Effects of Type of Plant upon Forage Value. There are thousands of plant species growing on the range, and many of these are important constituents of the animal diet. Although there are infinite variations in forage value among species, there are some similarities among various plant groups. The legumes, bearing nitrogen-fixing bacteria, are inclined toward a high protein content. Browse plants, being generally deep-rooted and tending to store in the stems rather than in the roots, do not decrease in protein, vitamin A, and carbohydrates during dry periods or during the winter as much as do grasses. Forbs generally do not cure well, being, in the nongrowing season, inferior as forage to both grass and browse.

Analytical results in California show that protein and phosphorus content is approximately the same in grasses, grasslike plants, and broad-leaved herbs, but broad-leaved herbs maintain lower crude fiber and higher calcium and potassium throughout the growing season than do the other two groups. Deciduous shrubs and trees contain a higher protein content than herbaceous plants. Crude fiber is low in deciduous trees and shrubs and in nondeciduous shrubs (23). The calcium to phosphorus ratio remained at 1:1 throughout the season in grasses; in grasslike species, it was 1:1 in the early leaf stage and 4:1 at maturity;

in broad-leaved herbs, it was 2:1 in the early season and 12:1 at late maturity; in nondeciduous shrubs the ratio ranged from 5:1 in the early stage to 16:1 in autumn; in deciduous trees and shrubs the ratio varied from 1:1 in the early leaf stage to 28:1 at maturity.

Browse species in New Mexico are more than three times as high in calcium and 61 per cent higher in phosphorus than grass in the fall (66). In general, the protein content of browse species is higher than that of dry grasses and forbs (28). An exception is the annual bur clover (*Medicago hispida*), which maintains its nutritive value, having a protein content as high as 15 per cent when dry. In Texas (60), the short grasses are higher in phosphorus, total mineral, and protein content than tall grasses. Shrubs and valuable forbs, especially legumes, are consistently higher in phosphorus than grasses.

Research in Utah (62) shows that, in the winter, salt-desert browse species contain an average of 6.8 p.p.m. of carotene, whereas salt-desert grass species contain only about 0.1 p.p.m. carotene. Thus most browse species grazed during the winter in the Great Basin area are good sources of vitamin A, whereas grasses are very poor sources.

Browse in Utah (12) in both summer and winter is higher in protein, calcium, phosphorus, and lignin than grasses. Grasses are higher in crude fiber and cellulose. Forbs on the summer ranges are comparable to browse in nutritive content. Stems in all cases are higher in crude fiber, lignin, and cellulose, whereas leaves are higher in ether extract, protein, calcium, phosphorus, and other carbohydrates.

Effects of Habitat upon Forage Value. Numerous studies dealing with the influence of habitat, chiefly climate and soil, upon the chemical composition of forages have shown various results. It has been shown (15) that the calcium content of plants decreased and the phosphorus content increased during periods of high rainfall and that, when rainfall was low, the reverse occurred. Scott (50), however, found that the amount of precipitation did not affect the mineral content of forage. Brown (10), studying selected pasture grasses, found that the crude-fiber content increased as the temperature rose from 40 to 60°F. and changed little with further temperature rise. When the plants were exposed to variable temperatures, the effects of high day temperatures appeared to be counterbalanced by low night temperatures. Studies in New Zealand (49) showed no correlation between soil and grass mineral content, except that soils low in phosphorus generally produced forage low in phosphorus. A study in Utah (13) dealing with the effect of vegetation type and site upon nutritive value of forage, showed that environmental factors and soil moisture were more important in determining the nutrient content of range plants than the chemical content of the soil, as determined by standard methods. Conversely, others (6, 43, 50) have shown that plants

are affected materially by the soil on which they grow, soils with high mineral content yielding forages high in minerals. In addition, the soil type may influence the species composition and the availability of the nutrients. When one principal nutrient is deficient, others are taken up by the plant in abnormal amounts, and an even smaller amount of the deficient nutrient is absorbed than normally (6). Studies on the effect of season, site, and soil upon *Symphoricarpos rotundifolius* showed season to be a far greater influence upon chemical composition than either site or soil (59). However, plants growing on highly productive sites contained more protein and less nitrogen-free extract than those on poor sites. Soil type had a very significant influence upon the total ash and phosphorus content of the plant and a significant effect upon protein content.

DIGESTIBILITY OF RANGE FORAGE

The study of digestibility of range forages has been neglected, and much remains unknown concerning the effect of species, stage of maturity, and climate. Experiments in Nevada in 1909 (34) were probably the first actual feeding tests for digestion determination on range forages. Digestion coefficient, or percentage digestibility, was determined for many species by feeding tests with range sheep. Depending upon the species, 50 to over 75 per cent of the dry matter was digested. Ash was the least available, ranging from 22.69 to 67.39 per cent. The digestion coefficients of protein ranged from 48.03 to 81.70, crude fat from 15.69 to 81.49, crude fiber from 35.90 to 74.38, and nitrogen-free extract from 60.16 to 86.10 per cent. Studies in North Dakota (11) on native grass hay showed wide seasonal variation in digestibility of total dry matter, mixed grasses being 59.72 per cent digestible to cattle in July and 45.33 per cent in October. In general, immature plants are higher in nutritive value and digestibility than are mature plants; and animals consume more and gain better on immature forage.

Bunch grasses in Washington are very low in digestibility during late fall (40). Total dry matter reaches a coefficient of digestibility of as low as 27.8 per cent for ewes. The grasses are more digestible when fed with protein supplements, and mixed range forage is more digestible than pure grass. Pregnant ewes are less efficient than lambs in digesting range forage.

Sheep ordinarily digest rations more efficiently than do cows, except for crude fiber. Cows digest crude fiber more efficiently than do sheep unless the proportion of concentrate to roughage in the ration is high. Then sheep are more efficient (22).

Studies on the salt-desert ranges of Utah (12) during the winter grazing season showed the following digestibility percentages for the various

plant constituents: ether extracts, 66 per cent; protein, 42 per cent; cellulose, 55 per cent; other carbohydrates, 64 per cent; crude fiber, 45 per cent; and nitrogen-free extract, 56 per cent. These data provide no index to digestibility of specific plants but represent the average of plants ingested.

It is known that with heavy utilization of range in the nongrowing season the content of digestible nutrients in the available forage decreases, and, further, the digestibility of these nutrients decreases.

This results when heavier utilization forces the animals to consume the less nutritious portions of the plants. See also pages 309 and 310.

A few studies have been made on individual plant species which are important winter forages for deer (Table 52). Some of these show surprisingly high digestibility values, considering the woody character of the material (51, 52).

TABLE 52. DIGESTIBILITY COEFFICIENTS FOR SOME COMMON BROWSE SPECIES AS WINTER FEED FOR MULE DEER

Species	Digestibility coefficients, per cent				Total digestible nutrients, pounds per hundredweight
	Protein	Ether extract	Crude fiber	Nitrogen-free extract	
Artemisia tridentata....	66.6	68.3	51.4	78.0	81.0
Cercocarpus ledifolius...	51.3	12.9	35.9	76.3	67.8
Juniperus utahensis...	16.8	58.9	33.7	70.4	63.5
Cercocarpus montanus..	48.5	37.6	31.8	60.0	49.6
Cowania stansburiana...	39.8	47.7	4.4	59.4	47.3
Purshia tridentata......	35.7	53.0	18.3	57.3	47.3
Prunus virginiana.... .	18.4	23.3	8.8	56.1	38.8
Quercus gambelii.......	10.7	38.4	16.6	53.6	36.2

ADEQUACY OF RANGE FORAGE

Insufficient work has been done on range forage to enable one to point out areas of specific nutritional deficiencies. However, from such data as do exist, it would appear that during the growing season both browse and herbaceous forage will supply ample amounts of the major nutrients. As forage matures, deficiencies may appear. Although many of the existing data have been secured from the northern desert-shrub type, it is likely that trends found to exist in classes of forage may exist elsewhere.

Most salt-desert grasses in winter are excellent sources of energy and furnish from a third to a half more energy than normally required.

However, most salt-desert browse plants are borderline or deficient in energy and must be supplemented in order to furnish adequate energy for grazing animals.

All grass species on desert ranges were found to be materially deficient in protein during the winter grazing season, whereas browse species were generally borderline or slightly deficient (12).

Phosphorus deficiency is the most common deficiency found on range lands. This is particularly true where animals are required to subsist on mature forage such as found on most winter ranges. There are many extensive range areas where supplementing the range diet with phosphorus has increased livestock gains and lamb and calf crops (9, 36, 42, 55).

Studies on the salt-desert winter ranges of Utah (12) showed that browse species were materially higher in phosphorus than were grasses. However, the browse species generally did not contain adequate phosphorus to meet the requirements of grazing animals.

It may be safe to assume that during the nongrowing season browse plants compared to grasses generally are relatively high in vitamin A, protein, and phosphorus, whereas grasses are likely to be higher only in energy-yielding values (14). Winter ranges composed primarily of browse require energy supplements to balance the ration. Grass ranges in winter generally require protein and phosphorus, and occasionally vitamin A if grazed for extended periods of time.

For additional information on supplementing range livestock and how these feeds can be supplied the reader is referred to Chap. 12, pages 293–296.

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CHAPTER 12

LIVESTOCK MANAGEMENT AND RANCH-OPERATION PROBLEMS

The range that furnishes the feed and the animals that consume the feed are the basic materials of the livestockgrower. Successful operation depends upon careful handling of both and upon the greatest possible harmony between the two. Livestock producers should not be concerned with the animals at the expense of the range, nor should range managers and administrators confine their attention to the range and ignore the livestock.

Scientific range research and the experience of pioneer ranchers have shown that it is possible to harvest and use the products of range lands without jeopardizing their future productivity. Proper balance between range and livestock can be obtained only by an understanding of the requirements and characteristics of various grazing animals as well as the plants.

KIND OF LIVESTOCK

By *kind* is meant the species of animal, essentially cattle, sheep, horses, and goats. Occasionally the term *class* is used synonymously or, especially, is applied to cattle, horses, and mules as one class and to sheep and goats as another. It is better used, however, to apply to particular ages, sexes, or types, such as steers, dry ewes, feeders, or breeders. By *breed* is meant a special group within the species having characteristics that differentiate them from others within the species, as Hereford cattle contrasted to Shorthorn cattle.

The various kinds of grazing animals, both domestic and wild, have certain characteristics that make them differentially adapted to ranges of various sorts. These differences are reflected both in the influence of the animal upon the range and in the influence of the range upon the animal.

An important consideration in determining stock adaptation is the vegetation. Different animals do not have the same forage preferences and so do not choose the same plants when given choice. Observation of

these preferences makes possible a wiser use of the range by grazing the kind of stock that makes best use of the existing forage.

Forage Preference of Livestock. Browse ranges are best adapted to sheep and goats. Of the two, perhaps goats can make the better use of shrubs. Since browse often grows in thick stands, larger animals may be prevented from working through and fully utilizing the forage present. Furthermore, sheep and goats prefer the forage produced on shrubby plants more than do cattle or horses. Though sheep eat grass in large quantities, most grasses must be young and green to be fully used. Other factors being equal, browse ranges should be stocked with sheep or goats for best results.

Sheep utilize forbs more fully than any other kind of livestock. Not only do they consume larger quantities of these species, but they also consume a greater number of species. Where forbs make up a large part of the forage, most satisfactory results are obtained from sheep.

Horses are the most selective of the domestic animals. They are primarily grass eaters and utilize relatively small amounts of other forage. The horse has an ability to utilize coarse grass unsurpassed by any other kind of stock.

Cattle are chiefly grass grazers, although they consume many shrubby species readily and obtain some forage from the broad-leaved herbs. Grass, browse, and forbs are preferred by cattle in the order named, the volume of the last two being small in relation to that of the grass (11).

Despite the preferences of animals, any kind of grazing animal can thrive on virtually any kind of forage. Digestion studies show no great differences in the ability of various herbivores to utilize various kinds of forage. Further, any animal prefers a variety of feed rather than any one species alone.

Forage preferences of animals are important in livestock poisoning (see page, 236). Whereas a given poison may be a constant threat to one kind of livestock, another may graze the same range with impunity.

Topography. Various kinds of animals respond quite differently to the physiography of the land. Cattle graze level land to best advantage, although rolling country can be fully utilized by them. Where the range is rough, cattle congregate on more level areas, such as valley bottoms or ridge tops, leaving the steeper portions unused or only partly used. This has direct bearing upon range grazing capacity (see page 323).

Proper stock numbers may depend as much upon correct distribution as upon total quantity of herbage present. It is not unusual on mountain range to see overgrazing and range deterioration on the best part of the range, even though the total forage is adequate. Under such conditions, both the range and the livestock are adversely affected. Many mountain ranges are mistreated because of failure to consider this factor. Range

examiners must realize the loss of forage which is inevitable on rough ranges when grazed by cattle. This does not mean that the animals cannot work steep slopes, for even cattle can and do traverse amazingly steep land. The willingness and not the ability of an animal to get into the steep areas always should be the basis of the range manager's analysis of range adaptation.

Utilization cuts are always necessary when steep land is grazed by cattle. Usable, not total, forage must be the basis for stocking capacity calculations.

There is some indication that cattle will overgraze important key areas on rough range before they are forced onto less accessible areas. Reducing numbers below a certain point results only in reduction of area used and no significantly lighter use on choice accessible areas. In such instances, stocking would need to be reduced far below the economically feasible point to eliminate excess grazing on choice areas. These areas then usually become *sacrifice* areas. Overuse of these sacrifice areas in valley bottoms and around water holes is justified if the manager is conservative as to the area involved.

Sheep are better adapted to grazing steep topography than other domestic animals, with the possible exception of the goat. Their smaller size, climbing instinct, and sure-footedness enable them to negotiate steep areas with less difficulty than larger animals, and they are ordinarily under the control of a herder and can be encouraged to graze steep slopes.

Rocky areas and poorly accessible mesas have important influences upon grazing. Studies of cattle range in the Southwest revealed that rocky areas were not used so heavily as those free from stones (11). Cattle cannot travel so well or so far over rocky terrain, and poorer utilization results. Many animals, especially the heavier ones such as bulls, develop sore feet on rocky areas and may become thin because of inability to travel far enough to obtain adequate forage.

Common or Dual Use. Since each kind of stock grazes most heavily on certain plant species and certain types of topography, most efficient range use likely can be attained by *common or dual* use, *i.e.*, by grazing more than one kind of livestock on the same range. Common use results in more uniform utilization of both species and areas than is obtained by single use, provided the combined numbers of each kind of animal are commensurate with forage production. A summer-range area grazed by sheep and a comparable range grazed by cattle were studied to determine the desirability of common-use grazing. It was found that the area would furnish 652 animal units of grazing when stocked with the proper proportions of sheep and cattle together. However, if the entire area were grazed by cattle alone, it would furnish grazing for 560 animal units, and when grazed only by sheep, it would furnish 306 animal units of grazing.

Thus, the area would furnish more grazing from common use than from single use and was judged 1.83 times more suitable for cattle than for sheep (8). The more kinds of animals grazing, the more likely that every species will contribute its share to the total forage consumption. Likewise, many kinds of animals will more thoroughly cover the range and make full use of steep and less accessible areas. This fact is recognized in the Edwards Plateau country of Texas where deer, cattle, sheep, and goats are commonly grazed together. Stockmen there find this system makes efficient use of rough topography and of all forage species.

Common use is especially important on ranges that support forage plants highly preferred by sheep, but not especially by cattle, and others preferred by cattle but not by sheep. Maximum efficiency of grazing can be obtained by one kind of stock only where the important dominants are especially adapted to their use. Cattle alone make as complete use of a level range that is 90 per cent grass as a mixed herd of cattle and sheep. Correct grazing demands the use of the range by that kind of animal or combination of animals which gives the most uniform use of the forage species and topography. If the major species are about equal in use factor for each kind of animal and the range is relatively level, little increase in grazing yield is possible from common use.

It should be clearly understood that common use of a range does not mean placing on the range animals of another kind in addition to the present stock; rather, they should replace some of the present stock. Common use does not imply double use. If grazing both kinds together makes for a more efficient use of the forage, total animal units grazed can be increased.

One frequently hears, especially from cattlemen, that sheep and cattle cannot graze together because cattle will not use a range that has been grazed by sheep. This may be true where sheep use the range so closely as to leave no desirable forage, but it is not true if each kind so grazes the range as to leave forage for the other. Cattle and sheep will graze a range at the same time, or either will graze after the other.

Exchange Ratios. The volume of forage consumed by various kinds of animals is related to body weight and body surface (see also page 261). Commonly, 5 sheep are considered equivalent to 1 cow when changing from one to the other on the range, although 6 to 1 is likely more proportionate to their body weights. This ratio, however, is profoundly influenced by type of range, and by age, sex, and breed of animal.

On federal ranges, animals under 6 months of age are not counted in determining permitted numbers. Since lambs on summer range are proportionately larger, mature faster, and are more abundant percentagewise than calves, a proportionately larger food supply is necessary for ewes with lambs than for cows with calves.

In actual practice, the suitability of the range is considered in determining stocking ratio. A proportionately larger number of sheep can graze on rough range, poorly watered range, ranges high in forbs and low in grasses, ranges having plants poisonous to cattle but less so to sheep, and ranges having pests or diseases more troublesome to cattle than to sheep. The standard exchange or conversion ratio based upon nutritional requirement is modified locally according to these factors.

As has been pointed out, many ranges are more efficiently used by cattle and sheep together. The conversion ratio, therefore, would be influenced. On a range now grazed entirely by cattle, some might be replaced by sheep on a very wide ratio. On a range now grazed by both sheep and cattle, the cattle would be entirely replaced by sheep only at a very narrow ratio.

Pests, Diseases, and Predators. Of importance under some circumstances in determining the kind of stock for a given range is the presence of various pests and diseases. In certain areas, stock have been precluded because of the presence of bloodsucking insects. Occasionally, on high mountain meadows the distress inflicted upon cattle will prevent their feeding normally and making satisfactory gains. It is better to graze with sheep, since their wool gives them greater protection. Other insects, such as the cattle botfly or ox warble fly, are specific to a certain kind of animal and do not interfere with the grazing of another.

Certain predators might determine the best adapted stock. Unusual concentration of coyotes makes sheep production very difficult, though they are of minor importance to cattle. Similarly, diseases often affect sheep only or cattle only.

Range Damage by Different Kinds of Stock. Comparative range damage by various kinds of livestock has received little scientific investigation, and opinions are based upon early observations. These were, commonly, that sheep were the most detrimental, and many early-day corrective measures applied to unsatisfactory ranges involved their removal. These opinions were based upon damage that followed increased sheep numbers and caused by overuse rather than by any feature inherent in sheep grazing. Actually, because they are under the control of a herder, it is possible to give the range greater protection when grazing with sheep. Overgrazed spots may be avoided, and the less heavily used areas may be made to support the stock. Conversely, cattle congregate in choice grazing areas such as meadows and canyon bottoms, where local overgrazing may cause serious erosion. Although this problem is not serious on nearly level plains, it is so serious on some rough mountainous ranges as to raise the question whether cattle should be grazed.

The ability of sheep to crop forage closely, together with intense trampling when they are permitted to bunch together, may result in

serious damage. Sheep, being smaller than cattle, probably cause less damage to the range by trampling than do cattle, provided that they are not bunched. Certainly, cattle cause more soil disturbance on wet hillsides than an equivalent number of sheep, provided the sheep are properly handled.

Because the cow and the horse are large and graze with a pulling motion and the sheep merely nibbles, the cow and horse pull more plants from the soil. Because sheep prefer the leaves of grasses, they do less damage to the stems and hence to the seeds than do cattle or horses.

Fig. 99. The razorback hog or piney-woods rooter, abundant in southeastern United States, is damaging to range because he feeds upon roots.

Sheep are more harmful to timber reproduction than are cattle because of their forage preferences (see page 214).

Horses do not tend to congregate but constantly seek areas of fresh feed. Having both upper and lower incisors, they are able to crop forage closely and for that reason may injure severely the individual plants. If horses are confined and made to crop closely, their effect may be extremely severe.

Goats are much like sheep, though hardier and capable of existing under very unfavorable conditions, which, undoubtedly, has given them a bad name. When forage is scarce, goats do great damage by chewing bark from woody plants. Because they are inclined to climb onto shrubs, breakage results. Where good forage is present, however, they are

fastidious and graze less destructively than sheep (29), although they travel more than either sheep or cattle (10). Goats often are kept for milk and are herded to a central headquarters each night. Such a practice results in concentration which destroys the range in the vicinity of the ranch headquarters.

Hogs, common on southeastern ranges, are extremely damaging because of their habit of rooting underground (Fig. 99). They are very harmful to coniferous trees (see page 90).

BREEDS OF LIVESTOCK

There are many breeds of cattle and sheep suitable for western range production. They differ in their characteristics and hence in their adaptability to various conditions. To some extent, the choice of breed is determined by local custom and habit. Modern breeds are widely adapted; however, certain characteristics of each breed make it ideal for certain methods of operation or certain types of range. For western ranges, the primary consideration in selecting a breed generally is its ability to secure forage under adverse conditions. This quality is known as *rustling ability*. Closely related to rustling ability is the ability to withstand cold weather and deep snow. The practical rancher has little use for any but the rugged animal that can care for itself and its offspring and come in from the range in good condition.

Cattle on the western range are grown for beef production. Almost everywhere the Hereford breed (Fig. 100) is the favorite because it is a heavy, rugged breed of unexcelled rustling ability. Other locally popular breeds are the Shorthorn, the Angus, and various crosses and breeds founded upon the Indian zebu or Brahman cattle (Fig. 101). The latter are big, highly resistant to high temperature and tick fever. Hence they are popular throughout the South. The Santa Gertrudis, resulting from crossing Braham bulls and Shorthorn cows, is the best-known of several new breeds and strains involving the Brahman.

There are many breeds of sheep adapted to the western range. Some were developed in England chiefly for their mutton qualities, with little regard to wool production. Others were developed in Spain, where sheep were kept for wool alone, with little regard to mutton conformation. Early production in the West followed the latter practice, for wool was more easily marketed. The Rambouillet, developed from early Spanish stock, became the most common breed, a position that it still holds. This breed is rugged, hardy, easy to handle on the range, and produces high-quality wool.

In order to increase mutton yield from the range, it is common practice to breed Rambouillet ewes with mutton-breed bucks such as Hampshire,

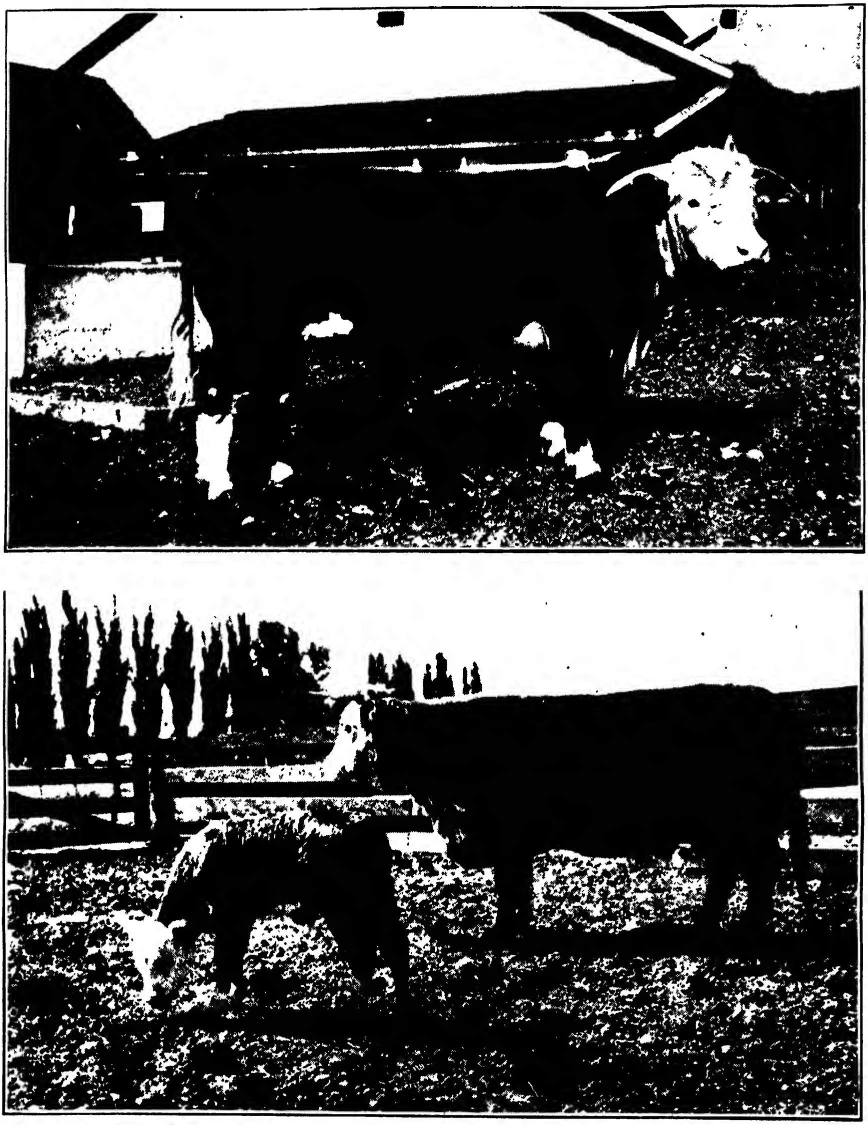

FIG. 100. Above is a top-ranking Hereford sire and below is an excellent cow with one of his calves. Parents of this type assure good calves.

Shropshire, Suffolk, and Lincoln. Ordinarily cross-bred lambs are not retained for breeding.

The Targhee breed, which was developed in western America from crossing the Rambouillet and Lincoln, primarily, is a dual-purpose animal with good-wool and good-mutton qualities. It is rapidly becoming popular with western ranchers. The Columbia and Corriedale are similar breeds.

The latter are larger breeds which consume correspondingly more forage, hence the fact that they produce more meat per animal may not mean that they are superior breeds on the range.

In restricted sections of the West, goat raising is of importance. Texas and the Southwest are the principal areas devoted to their production. There are two general types of goats, the Angora and the milch goats. Of the two, the former is of greater importance in the United States. The Angora is kept principally for its mohair, which is used in a number

FIG. 101. Brahman or zebu cattle from Burke Brothers ranch, Corsicana, Tex.

of industries. Some 90 per cent of American mohair is produced in western Texas (6).

THE EFFECT OF QUALITY OF STOCK UPON RANCHING ECONOMY

An important means of increasing production from ranching is using high-quality livestock. Increasing the quality of stock means higher returns per animal. This permits a greater value of salable products from the same or fewer number of animals. Improved quality results, therefore, in improved range conditions through less intensive use. This may not mean that weight gain per unit of feed consumed is greater in better-bred animals; but a larger percentage of the carcass is usable, and also the animals bring a higher price.

Sometimes ranchers overlook the importance of good quality in rams and bulls and are lax in removing low-grade animals from the range. Good males are a far better medium for building up the herd than are good females, and the modern rancher should demand purebred rams and well-bred if not purebred bulls with thick, blocky body conformation.

BREEDING RANGE LIVESTOCK

The primary purpose of a range cow is calf production, and the calf generally must be suitable for the middle-western feed lot or the eastern market. The more of these calves produced and the better they are suited to these purposes, the more effective is the function of the cow. The western range cow is an animal bred to withstand hardships and to work for her feed and she does this well, but a healthy and well-cared-for animal will produce the best.

The percentage yield of calves and lambs is one of the most important factors affecting the success of a ranch. The importance is apparent, for the livestock increase comprises, essentially, the salable product. This factor can be varied more than almost any other through skillful management, since it is intimately dependent upon quality of the range and the breeding and feeding practices.

Calf Crop. Cattle ranchers, almost universally, have been content with too low a calf yield. Remarkable increases result from improved handling methods and improved range conditions. On the Santa Rita experimental range in Arizona, a calf crop of 82.7 per cent was secured over an 11-year period, the highest for an individual year being 88.8 per cent. Operators on the surrounding ranges for the same period secured a calf crop of 55 per cent (12).

Studies in Wyoming (31) showed that the calf crop is vitally important in determining rate of return from investments. Calf crops, at spring branding, averaged 70 per cent and varied between 59 and 94 per cent. The income increased rapidly with an increase in calf crop up to about 80 per cent, above which increases were slight. Above 85 per cent, income decreased, the investigators concluding " . . . it would seem that in securing a calf crop above 85 per cent the necessary increase in the expense of labor, feed, and investment is greater than the increase in the number of calves will warrant."

Nine-year studies in South Dakota involved grazing mixed prairie vegetation to obtain utilizations of 63, 46, and 37 per cent. Calf crops weaned were 55, 60, and 85 per cent, respectively. Weaning weights per cow were 186, 202, and 323 lb. and per acre 18, 13, and 14 lb., respectively (19).

Unsupplemented cows on California annual grass ranges produced calf

crops of 60.0, 77.8, and 72.5 under heavy, medium, and light grazing intensities, respectively (4).

On Montana short-grass ranges, calf crops of 79, 85, and 85 per cent were secured under heavy, medium, and light grazing, respectively (16).

Results of experimental grazing in Oklahoma did not show significant differences among heavily, moderately, and lightly grazed pastures in per cent of calf crop which varied from 92 to 96. Weaning weights, however, were much greater on lightly grazed range (22).

Several studies appear to show that cows, once they are bred, do not resorb or abort the calf except under unusually severe conditions, but that conception may be influenced rather readily by plane of nutrition.

Lamb Crop. The average western lamb crop varies between 70 and 80 per cent, in spite of the fact that it has been demonstrated that 100 or even 140 to 150 per cent is possible on the range (23). Lamb yields

TABLE 53. NUMBER OF LAMBS SAVED PER 100 EWES, BY STATES, 1931-1935
Data from Mann (21)

State or region	1931	1932	1933	1934	1935	Average
Arizona	72	65	70	73	75	71
California	90	81	78	89	88	85
Colorado	82	73	77	87	75	79
Idaho	101	87	90	94	88	92
Kansas	108	97	109	108	108	106
Montana	83	77	74	83	77	79
Nebraska	106	98	109	110	105	106
Nevada	81	45	56	69	70	65
New Mexico	68	52	50	57	64	58
North Dakota	106	105	98	93	89	98
Oregon	92	81	81	91	84	86
South Dakota	91	83	83	80	78	85
Texas	75	72	72	48	46	63
Utah	75	52	62	72	65	65
Washington	104	104	98	106	99	102
Wyoming	83	67	54	75	65	69
Western states	84	73	72	75	71	75
Corn-belt states	105	105	102	103	107	104
Far-eastern states	104	103	105	99	104	103
United States	89	81	80	82	81	83

obtained on a demonstrational area in New Mexico are enlightening. Though the normal lamb crop in the surrounding area was 57 per cent, it was possible, through more careful handling methods and improvement of range conditions, to secure a crop of 106 per cent (1). The great variation in average lamb crop among western states is shown in Table 53.

Eleven-year records of sheep grazed under moderate and heavy stocking on salt-desert winter range in Utah showed 88 and 79 per cent average lamb crops, respectively (17). Moderate grazing was at a rate of 15 sheep-days per acre; heavy grazing at the rate of about 19 days.

Management Factors Affecting Calf and Lamb Crops. Since calf and lamb yield are of such extreme importance to the range operator, it is necessary to consider all factors determining this yield on the range.

An insufficient number of males is an item of great importance, particularly in the case of cattle. Even though the number of bulls is adequate, because of other factors such as steep topography and the use of old inactive bulls, the distribution may be poor, thus effecting the same result as would an insufficient number. Results in Montana indicate that range riding in order to ensure good distribution may increase the calf crop by as much as 15 per cent (32). Where topography is favorable and, particularly, if the range is enclosed by a fence, fewer bulls will be needed.

One of the most important means of increasing the yield of range cattle is to provide breeding pastures. Small, relatively level areas of high carrying capacities, if fenced, can be made to serve this purpose. Mature cows and bulls are placed in these areas during the breeding season. This practice increases the effectiveness of the bulls, lowering the number needed, and at the same time resulting in greater calf crops. Increases of 30 per cent have been secured in calf crop from mountain range by breeding in high quality, fenced pastures.

Another advantage is that small-pasture breeding makes possible birth of calves over a relatively short period of time, giving obvious advantages in marketing, for even-aged animals command better price. Bulls can be better conditioned for short and definite breeding periods, and the difficulty of distribution is minimized. Though use of a breeding pasture is not feasible on all ranches, many operators could profitably and with a minimum of expense include such a program in their management plans.

The fenced breeding pasture is of especial significance to operators who use National Forest summer range. On open ranges, poor bulls owned by another operator may breed the good-quality cows. There is little incentive for an operator to buy high-quality bulls unless they breed his own cows, a factor which is uncontrollable on open range.

Bulls, as long yearlings, occasionally are allowed to breed a few cows, but this practice generally is considered inadvisable. Assuming active use to start at two years, the average bull can give good service for 6 years and some for 8. A younger bull is preferable for range use, for he is smaller and can move around more easily. Old bulls often remain in the most accessible and least rocky areas. To avoid inbreeding, individual

bulls normally should not be kept longer than 3 years for general range service.

The number of bulls necessary depends upon several factors. Under ideal conditions, a healthy mature bull can breed as many as 50 cows during a normal breeding season. However, under most range conditions, 20 to 25 cows per bull is preferable; even with this low ratio, some herding to effect good distribution of the bulls is desirable if the range is rough. At this ratio, and with reasonable care of the herd, the breeding season should not need to extend beyond 2 months.

Bulls should not be allowed to run indefinitely with the cows. The few extra calves that are gained are off-season and hence costly to handle. A better practice is to cull cows that are slow breeders.

True oestrum in the cow lasts only about 12 hours, and often much less, and occurs, normally, at intervals of about 3 weeks. Range cows, then, are subject to breeding only once if the bull is with them 3 weeks, twice in 6 weeks, and three times in 9 weeks. With good distribution of bulls, the chances of a pregnancy in three heat periods are high; if the cow fails to become pregnant, she should be culled.

When long-yearling heifers are run with the herd, a considerable percentage are likely to breed. Small and extra-young animals have difficulty calving as 2-year-olds and death loss is high among both heifers and calves. Many operators, therefore, separate yearling heifers from the herd. Recent research, however, indicates that big, well-grown animals can safely calve as 2-year-olds and future production will not be decreased. Breeding big 2-year-olds will materially increase ranch production.

Rams should be used sparingly as long yearlings; 2-year-olds are much preferred. Ewes generally breed to lamb first at 2 years of age. Under range conditions, they ordinarily should be culled at about 6 years of age, though this varies greatly, depending upon the type of range. Old ewes can be used a few years on farms or under intensive shed-lambing types of operation. A yearling ram can serve about 20 ewes, whereas a 2-year-old ram or an older one can serve 50 to 60 ewes under ideal conditions. Under open-range conditions, 30 to 50 is a usual number. Sufficient bucks to limit the breeding season to about 5 weeks is desirable. Since oestrum occurs in the ewe at intervals of about 17 days, a breeding period of 5 weeks will ensure two opportunities for the ewe to breed. Thereafter, the bucks are placed in a separate herd, usually on farm pastures. They should be fed a good conditioning ration before the breeding season but should not be too fat. Breeding should take place 5 months before lambing is desired.

The condition of the female is important among the factors affecting yields. Conditioning animals by supplemental feeding or *flushing* during

the breeding season is sometimes recommended (see page 266). This is of especial value during drought years or when weather is unusually severe.

Research on feeding concentrates to range ewes in Montana showed that feeding before breeding time, during breeding time, during early pregnancy, and during late pregnancy resulted in increases of 10, 9, 5, and 4 per cent, respectively, in numbers of lambs born. A lamb crop average of 145 per cent was secured by feeding at all times contrasted with 110 per cent when no feeding was practiced (13).

Cattle studies conducted on annual grass ranges in California foothills showed similar responses from supplementing cows with concentrates from August 1 to February 1. Depending on intensity of grazing, supplemented cows produced calf crops of 78.4 to 86.5 per cent, whereas unsupplemented herds produced only 60.0 to 77.8 per cent (4).

Supplementing phosphorus or fertilizing pastures with phosphorus in south Texas increased average calf crop from 76.4 per cent born to well over 90 per cent (26).

Calving and Lambing. It is not advisable in cold countries for calves to be dropped in very early spring, nor should the calving period be spread over too long a period. Seldom, in the North, should calves be dropped before the middle of April. The loss of weak calves more than offsets any advantage that can be gained in size.

Calving too late is equally inadvisable. For calves to enter the winter when they are too young to forage for themselves puts heavy demands upon the mothers as well as upon the calves. In southern range areas, fall and winter calving are not unusual; but, even there, spring calving is almost always preferable. July to September calving is least desirable because of excessive heat and insect danger (33).

The lambing season is highly variable in the range states, most operators working toward early lambing in an effort to reach better markets. Where ewes are kept on farms during the winter, or on winter ranges of comparatively mild temperatures, lambs frequently are dropped during December, January, and February, and often lambing sheds or tents are used. On cold and unprotected ranges, lambing in April and early May is more common. In general, early lambs are marketed as fat lambs direct from the range, whereas late lambs go to the feed lot for fattening. The so-called *hothouse lambs* which are popular on the market, are born in the fall or early winter and are marketed at 2 to 4 months, weighing 50 to 60 lb.

Sheds make possible earlier lambing and a greatly increased lamb crop, though their use increases the demand for labor and feed. Substituting a tent for a shed is popular in some areas. Ewes with new lambs generally are moved into small pens within the shed, where they remain for about

a day or until the lamb is feeding normally. Thereafter, they are placed in small groups, which gradually are recombined to form the normal summer herd.

Lambs are docked and the males castrated almost universally in range operations. Docking usually is done with a knife or hot iron, and the tail is removed about 1 inch from the body. A newer technique of placing a tight elastic band over the tail until it sloughs off appears highly practicable. These operations take place about 10 days after birth.

Handling Livestock on the Range. Many range livestock live yearlong without supplemental feed, protection, or any special care. However, sheep in most of the West are attended by herders, with the exception of parts of the short-grass plains region, parts of Texas, and a few local areas where coyote-proof fencing has been tried. It is doubtful whether fenced ranges ever will become generally practicable for the sheep operator on most western ranges.

Daily handling of sheep under the herder system varies. In general, the herder does not push the animals or crowd them but merely allows them to spread and work over the range as they will. The chief purpose of the herder is to protect the animals and to guide their movements.

Sheep move from the bed ground at an early hour; and since this is the hour of the coyote, the herder should be active. When late morning or midday arrives, the animals shade up until early evening. In the meantime, the herder moves camp equipment to a new bed ground and places salt where the animals are to come. The sheep graze, then, to the new bed ground where they settle at dark (see page 327).

Ewes with lambs generally are run in bands of 500 to 1,500 head on summer ranges; after lambs are marketed, the herds are combined. On the winter range, herds of 2,000 to 3,000 head are not uncommon. Barns or sheds are almost never provided except in certain areas at lambing time.

Shearing of ewes is usually immediately before or after lambing. The date varies from about February in the Southwest to June in the northern areas (Fig. 102). The shearing is now done largely by power shears operated by traveling companies. Cooperative shearing plants are common in some areas. Range sheep are shorn only once during the year except in a few areas, mainly southern. Immediately after shearing, the sheep are branded with the owner's mark by means of a special branding paint and, often, dipped to kill external parasites.

Cattle are almost never herded in America and many roam unfenced range. In areas where winter snows are heavy and temperatures low, a shed may become a necessity; otherwise, a too large percentage of the feed goes to maintenance and too little to calf production. It takes large quantities of feed to keep an animal in cold weather. In by far the greater

part of the West, however, sheds are not necessary, though usually a tree grove, lean-to, or some natural protection is highly desirable (Fig. 103). Undoubtedly, the biggest cause of death losses in both sheep and cattle is poor nutrition on cold and snow-covered ranges during winter.

In many areas, hardy cattle do well on the range without additional feed until January or even February; but pregnant animals, older animals, and those in poor condition should be supplied with hay or concentrate in northern areas. In about the southern half of the western range yearlong grazing without supplements is not unusual.

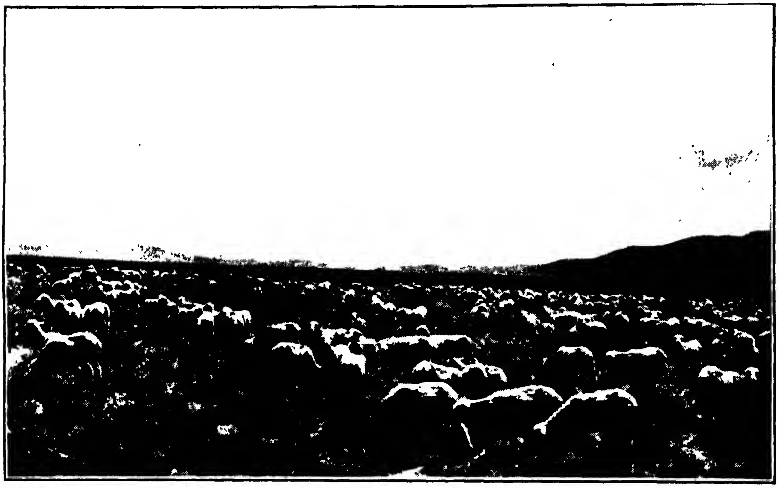

FIG. 102. Ewes on sagebrush range just after leaving the shearing corral in early spring.

Animals will not forage well after feeding is begun, so it should be delayed as long as is possible without damage to the cows. Careful supervision should be maintained, and weak animals should be added to the supplemented group. During heavy storms and during about 6 weeks before calving, the breeding cows should receive especial attention. A mother cow should be in good flesh but not fat. During early spring, about 1 lb. per day of concentrate such as cottonseed cake or grain will help the cow greatly. Feeding on the range should not be done in the same place each time. Where possible, the feed should be taken to the cattle, for this lessens range trampling.

Spring calves gain heavily during fall months when they have learned to graze and are still nursing. This dual feed supply should be maintained, and weaning should be delayed as long as possible without impairing the condition of the cows. In general, calves should be 6 to 7 months of age before weaning.

Weaning is accomplished by separating the calves from their mothers. They should be fed or placed in excellent pasture during this period. Even after several weeks, some calves find their mothers again; it is best, therefore, that they be kept permanently from the cow herd.

Supplemental Feeding. Giving extra feed to livestock while on the range is a complex problem involving matters of nutrition, balancing the seasonal feeds, and producing the greatest amount of marketable livestock with minimum expenditure. Problems of supplemental feeding are essentially economic, and the factor that will decide whether feeds should

FIG. 103. A low-cost shelter designed to give protection to livestock during the winter. The shed is open on the south but protects the animals from cold north winds and drifting snow.

be supplied will be the cost balanced against the additional production returned.

Drought is expected on western ranges at frequent intervals. When forage is deficient, either numbers must be reduced or additional feeds must be supplied. Chopped soapweed and sotol, and also burned cactus, are common emergency natural feeds in the Southwest, but they are not ordinarily recommended. Hay is the usual supplement in the West during drought emergencies, alfalfa being the most common because it is easily grown, high-yielding, and high in protein. More concentrated supplements are used as well, especially when the animals are far from the source of supply. Common concentrates are corn and other grains,

although a popular feed is cottonseed or soybean either in meal or cake form. Because of their high protein content, the latter most nearly balance the material furnished by most range forages.

The biological necessity and economic advisability of winter supplementing must be decided on an individual basis. In general, some weight loss is expected during winter, and healthy animals soon regain their weight when green forage again is available. But animals must never be allowed to become weak because they are subject to disease and may fail to produce normal young or to be able to nourish the young. Pregnant cows and ewes should be watched closely, especially during the 4 to 6 weeks prior to producing young. Additional feed often pays dividends during this critical period.

During heavy snow periods is a dangerous time for livestock, especially if the snow is crusted to prevent their reaching feed. During unusually cold weather, animals may also need additional feed because of high energy requirement. Death losses from winter storms during severe years often are excessive. Since it is sometimes difficult to reach stock when roads are blocked by heavy snow, common practice is to store hay or concentrates on the range awaiting emergency need.

Supplementing sheep which are attended by a herder is a relatively easy thing, but adding to the diet of cattle often involves considerable extra labor. Feeding concentrates to cattle by mixing them with salt appears to be a practicable procedure. Regulating the percentage of salt regulates the consumption of supplement. The percentage varies with (*a*) supplement consumption desired, (*b*) distance from water, (*c*) amount and quality of natural forage available, (*d*) season of the year, and (*e*) the degree of salt tolerance of the cattle, which seems to develop as feeding continues (22). Water consumption appears to be about doubled when salt intake reaches ½ to 1 lb. per day levels, but no harmful effects are apparent if sufficient water is available.

Under average conditions about 1 part of salt to 4 parts of cottonseed meal resulted in 2-lb. daily intake of meal by weaner calves. A ratio of 1:2.7 was necessary to supply 2 lb. of meal to yearling steers and a ratio of 1:2 gave 1-lb. meal consumption (28).

Mixing salt and meal is an effective method of improving distribution of cattle over the range, since they will readily move to otherwise lightly used parts of the range when drawn by the salt-meal mixture (2).

Addition of vitamin A supplements may be desirable during the nongrowing season, especially on grass ranges. Certain minerals may be required yearlong on restricted areas where deficiencies occur. Over the range area as a whole, phosphorus is far the most important of these. Phosphorus deficiency is especially severe in the nongrowing season.

The most commonly used phosphorus supplements are bone meal and

monosodium phosphate. These are frequently fed as a 50 per cent mixture with common granulated stock salt or fed alone in a separate container free-choice. When protein or other supplements are added, the phosphorus material can be added to the pellet in small quantities of adequate proportions to satisfy the requirements.

Experiments in Texas (26) showed that phosphorus deficiency could be prevented by feeding bone meal in self-feeders, by adding disodium phosphate to the water supply by automatic regulator devices, or by fertilizing the range with phosphorus. Unsupplemented cows produced

Fig. 104. A partly filled trench silo in Texas. This structure has a capacity of 1,000 tons. (*Courtesy of U.S. Soil Conservation Service.*)

93 lb. of calf per acre; cows fed bone meal, 116 lb.; cows receiving phosphated water, 143 lb.; and cows on fertilized range, 176 lb. Except during drought, fertilizing range solved the deficiency problem and at the same time increased the grazing capacity of the range as much as 84 per cent and the phosphorus content of the grasses by 150 to almost 300 per cent.

For further information on supplemental feed requirements of livestock the reader should refer to Chap. 11.

Feeding during Winter. Many western animals are wintered in pastures or feed lots under close supervision. Removing livestock, especially cattle, from the range during most severe winter seasons is becoming increasingly common. Comparatively few animals live yearlong on the

northern ranges today. Cheap and coarse feeds can be combined in a ration with concentrates to provide for maintenance of livestock at a surprisingly low cost, and even relatively long feeding periods need not be unduly expensive. Winter-feeding experiments showed that beef cattle fed 10.5 lb. of straw and 2 lb. of cottonseed cake made good daily gains. Straw and as little as 1 lb. of cottonseed cake, or straw and 5 lb. of hay per day will maintain the weight of cattle during the winter. Sheep do not use straw so effectively, though they can use small amounts to advantage.

The use of the trench silo (Fig. 104) has demonstrated the practicability of silage for the overwintering of cattle. This provides a cheap method of storing winterfeed.

The possibilities of cheaply wintering livestock on harvested forages are increased by the fact that it is necessary to supply a ration of only an intermediate level of nutrition. As long as stock are not emaciated and weak, they ordinarily will not be reduced in production.

SALTING PROBLEMS

One of the most effective methods of managing range livestock to ensure proper range use and greatest gains is proper salting. It is known that, with sufficient salt, livestock are more contented and more easily handled, are healthier and freer from disease, and make better gains and develop better. Experiments upon dairy stock (3) showed that animals develop a great craving for salt almost immediately after being deprived of it. Their appearance, weight, and general condition were not profoundly influenced, however, for from 1 to 12 months. Thereafter, loss of appetite and decline in general health occurred, resulting in a sudden and complete breakdown. Chlorine rather than sodium was the most essential element.

Number and Location of Salt Grounds. The number of salt grounds depends upon the topography and the kind of stock. Animals cannot go great distances for salt or water if satisfactory use is made of the range. If the topography is level or rolling, salt grounds 2 miles apart may be entirely satisfactory. More frequently, 1 mile apart is preferable.

It has been customary to locate salt grounds according to convenience rather than according to a well-developed plan. This resulted in salt being distributed along drainages and other places readily accessible. Since livestock naturally congregate in these places, this served to increase grazing concentration. It is commonly believed that animals desire water after salt and that, by locating salt near water, excessive travel is prevented. Observations have shown that this is not necessarily true and that, as frequently as otherwise, animals take salt and leave without drinking when the two are at the same location (11).

Records taken by automatic devices in mountainous summer ranges of California (5) showed that generally 5 to 8 hours elapsed between salting and watering of range cattle. Direct trailing time was only about 20 minutes yet observations showed that salt was obtained only when reached during the normal grazing circuit. On an average, cattle took salt 2 days out of 3 with little regularity as to time of day. Eighty-five per cent of the watering occurred in late afternoon and early evening, however.

Thus, in locating salt grounds, areas in proximity to water and low saddles between drainages should be avoided, since the use on these areas will be complete without the added attraction of salt. Some parts of mountainous range generally are poorly utilized because of difficulty in reaching them. By placing salt in such places, it is possible to get more complete use of the forage. Areas on which the vegetation is not palatable will be more completely used if salt is placed on them.

No exact and generally applicable rules can be made for the location of salt grounds, but certain principles can be followed. Locate salt grounds on ridges, knolls, benches, openings in timber or brush, and gentle slopes. These areas should be easily accessible and should provide a sufficiently level area for the stock to move around the salt ground without difficulty.

Quantity of Salt. Little accurate information is available on the amounts of salt needed on the range, although such information is important to a salting plan. Undoubtedly differences in kinds of stock, condition and kind of forage, and climate all influence this factor. Since salt is inexpensive and may be used to advantage in effecting the proper distribution of stock, it is likely that ample amounts should be provided, even though the consumption may exceed the actual needs of the stock.

It generally is accepted that more salt is needed in the spring when the forage is succulent than in the fall. Experiments in Kansas with two-year-old steers showed their salt requirement to be 2.83 lb. per head per month during the spring but only 1.20 lb. in October (15). In contrast, studies in southern Arizona showed greater salt consumption while feed was dry than during growing periods (30). The average salt consumption of Hereford cows was 3.15 lb. per head per month, the greatest consumption being in winter when feed was dry, and the least consumption in late summer when forage was green.

Salt requirements are calculated to include loss by weathering. Sheep generally are allowed from ¼ to ½ lb. per month except on salt-desert ranges where salt generally is not supplied. Cattle are allowed 1 to 2½ lb. Horses may require somewhat more than cattle.

Salt consumption by wild animals, especially rodents and big game, sometimes makes a considerable difference in the amount required on the range. Data on quantity thus consumed are meager, though studies

in Arizona indicate that 10 deer will consume 1 lb. of salt per month in the summer and ½ lb. in the winter (24).

Salt Content of Forage. The type of vegetation on the range greatly influences the quantity of salt necessary. Many western soils are high in alkali, and these natural salts are taken up by vegetation in large quantities. Analyses of forage plants in New Mexico (14) showed *Distichlis*, *Dondia*, *Artriplex canescens*, and *Sarcobatus* to have 0.17, 0.93, 0.08, and 1.11 per cent chlorine, respectively, or about the equivalents of 0.28, 1.53, 0.13, and 1.83 per cent salt. A number of native plants averaged 0.30 per cent chlorine or 0.495 per cent salt.

Range cattle are believed by some investigators to consume more salt when grazed on browse forage than when grazed on grass and weeds (7).

Animals on green feed consume considerably more salt than do those in the feed lot, and milking animals require more than do dry animals.

These variations in salt requirement and salt content of forage make evident the likelihood of widely different amounts of salt being consumed on different ranges and at different seasons.

Salt in Drinking Water. On many western ranges, water available to livestock is highly salty, containing often as high as 1 per cent of various kinds of salt. Thirty-one wells dug in the state of Utah (18) averaged 0.12 per cent equivalent of sodium chloride in their waters, varying between 0.003 and 0.896 per cent. Contents of total mineral solids as high as 6.71 per cent were recorded. On the assumption that cattle drink 10 gal. of water per day with an average of 0.12 per cent sodium chloride, the water of Utah desert wells should supply to each animal almost 3 lb. of salt per month. Even under such circumstances, however, it may be desirable to provide salt; its cost is nominal, and it has been observed that in some instances cattle take commercial salt in spite of the presence of natural supplies (7).

Natural Salt Licks. Throughout the West, salts occur commonly in soils. These salts are usually chlorides or sulfates of sodium, potassium, or magnesium, though many others occur. Spots containing unusually large quantities may become *salt licks* where animals, sometimes because of lack of proper range salting and sometimes in spite of other sources, consume large quantities. Naturally, large quantities of soil are consumed and, occasionally, undesirable salts. Deaths of cattle have been reported in Montana from balls of earth in the stomach after eating salty earth (7). Similar deaths of sheep in southern Utah have been observed. Analyses of several salt licks have shown that inappreciable amounts of salt were present. Stockmen should therefore be very certain of the quality of the natural salt licks before they rely upon them.

Kinds of Salt. Several factors influence the choice of the form of salt to use on the range. Ability to withstand weathering, hardness, ease of

distribution, facilities for protecting salt, and the cost—all may influence this. Many types of salt are used, the most common being rock salt (mined chunks containing various amounts of foreign matter), pressed block salt, and granulated salt. Since sheep are given a small amount of salt at frequent intervals and it is convenient to keep a supply on hand, granulated salt is preferred, for animals can more quickly satisfy their needs. Thus fewer containers need be supplied, and the animals are more quickly bedded down.

In Kansas, it was found that in using granulated salt for cattle, if it is placed on the range only at the first of the grazing season, an allowance of 5.25 lb. per head per month must be made to allow for weathering, 2.83 lb. of which is actually licked and 2.42 lb. lost in weathering (15).

Salt-hungry livestock should not be given access to unlimited amounts of granulated salt, for death may result from excess consumption.

Because of the greater ease of distribution and because containers are not necessary for the harder block and rock salts, these are used more often in salting cattle. Of the two, rock salt is the harder and resists weathering more effectively, but the softer blocks are more easily consumed by livestock and are generally preferred.

Whether or not salt is supplied in containers of one kind or another depends largely upon the type. With block and rock salt, containers are not a necessity, though certainly they are of value in reducing losses and in keeping the salt clean. If granulated salt is used, salt containers are a necessity. Heavy lumber boxes serve very well and ordinarily are made 9 to 14 inches wide, 6 to 12 inches deep, and 10 to 12 ft. long. They should not be watertight. Smooth wire, stapled onto the edges, will protect the box from gnawing by animals (7). On cattle range, troughs should be strong and sturdy enough to prevent their being broken, moved about, or turned over. Hollowed logs are good for this purpose. In the case of sheep, new bedding grounds are established frequently. Since salting is done on these areas, light containers that can be moved readily are desirable. Canvas troughs and metal pans that telescope into each other and are easily handled have been used successfully.

RANGE-MANAGEMENT PLANNING

The operation of a private ranch is one of the most complex of all business operations. It involves conservation of resources, planning of livestock management, buying and selling, construction and maintenance, and numerous other diversified activities. Such a business demands careful study and planning that lead to unified effort toward a known goal. It is of great importance not only to the conservation of the range but to the economic success of the operator that such a plan be in writing.

Although the most desirable plan is the product of scientific study and analysis by trained management experts, the stockman can benefit from personal study and thought followed by an organized plan of action. It is highly important that a rancher make a careful inventory of physical conditions and resources, for the entire operation of a ranch depends upon these resources, and complete understanding of them is essential to planned operation. Experience indicates that many ranchers never have taken the time to inventory their resources.

A similar plan is desirable covering the administration of large tracts of federal land. The range administration plan endeavors to give a word picture of the livestock industry and the range conditions as they are and the part that they play in the economic and social affairs of the community, as well as details of range management.

Theoretical and idealistic practices should give way to practical, economical, and tested methods that are of known effectiveness and feasibility.

It is well in proposing adjustments under the management plan to indicate (*a*) immediate adjustments, (*b*) gradual or delayed adjustments, and (*c*) the final goal toward which the plan aims.

The success of such a plan depends not alone upon the care and foresight with which it is developed but also upon the zeal with which it is followed by both administrator and livestock operator.

The following outline of a ranch-management plan was developed as a guide and includes many suggestions that are not universally applicable. A ranch plan will include certain livestock handling techniques not of concern to the administrator of public land. Likewise, a public-land-administration plan will include some details not applicable to ranch operation. Inappropriate sections are, of course, omitted in using this outline.

RANGE-MANAGEMENT PLAN

I. Physical conditions and resources
- *A*. Land resources available
  - 1. Owned range
    - *a*. Geographical location
    - *b*. Area size and boundaries
    - *c*. Elevation
    - *d*. Topography
    - *e*. Soils
    - *f*. Erosion conditions
  - 2. Rented range
  - 3. Public range
  - 4. Cultivated land
- *B*. Climate
  - 1. Rain and snow
    - *a*. Expected quantity
    - *b*. Variability influencing forage production

c. Distribution of precipitation
d. Snow season and expected depths
e. Influence on grazing dates
2. Evaporation
3. Temperature
4. Wind
C. Forage.
1. Vegetation types and description, original and present
2. Grazing capacity of range by seasonal units
3. Customary use of range by units
4. Cost per animal month
a. Rent of leased land
b. Grazing fees on federal range
c. Interest for investment on owned land
5. Condition of range by units
6. Kind of stock to which adapted
7. Season usable and growing season
8. Poisonous plants
9. Cultivated crops produced and yields
a. Kinds produced
b. Yields
c. Cropping schedule
D. Water
1. Developed resources
a. Location
b. Type of development
c. Quantity correlated with range capacity
d. Distribution or spacing
e. Season of availability
2. Undeveloped resources
E. Improvements
1. Buildings and sheds
2. Fences
3. Corrals and chutes
4. General equipment
II. Operation and management
A. Livestock inventory
1. Kind of stock
2. Numbers
3. Age
4. Grade
B. Seasonal distribution and movement
1. Approximate dates of movement
2. Trailing or transporting program
C. Supplementary feeding
1. Feeds used
2. Source of feed
3. Method of feeding
4. Location of feed ground
5. Usual season of feeding for each animal type
6. Cost of feeding per animal-month

D. Livestock-handling practices
  1. Breeding
    a. Season
    b. Sex ratio
    c. Breeding program and genetical aims
  2. Calving or lambing
    a. Location
    b. Season
    c. Supervision and mangement program
    d. Calf- and lamb-crop percentage
  3. Branding, castrating, docking, etc.
  4. Weaning
  5. Disease control
  6. Marketing
    a. Season
    b. Age of marketed animals
    c. Culling practices
    d. Location of market
    e. Transportation to market
    f. Method of marketing
  7. Purchasing
    a. Age of replacement
    b. Numbers needed for replacement
    c. Bull or ram source
    d. Cow or ewe source

E. Interrelated demands upon land
  1. Farming
  2. Mining
  3. Wildlife
  4. Recreation
  5. Timber
  6. Watershed

III. Proposed physical adjustments
  A. Range improvement
    1. Water development
    2. Fence and corral construction
    3. Trail and driveway construction
  B. Forage improvement
    1. Seeding
    2. Brush control
    3. Poisonous-plant control
  C. Soil protection and stabilization
    1. Contour furrows
    2. Water spreaders
    3. Check dams
  D. Rodent control
  E. Insect control
  F. Predator control

IV. Proposed use adjustments
  A. Livestock
    1. Changes in kind, age, or grade of stock

2. Changes in stock numbers
   a. Plan of adjustment
   b. Effect upon economy
3. Changes in sex ratio
4. Changes in breeding practices
5. Adjustment in range practices
   a. Grazing systems
   b. Salting
   c. Trailing
   d. Herding or riding
6. Adjustments in marketing and purchasing
7. Wildlife adjustments and management

B. Land and forage
1. Adjustment in range use
2. Purchases, sales, exchanges
3. Supplemental forage
   a. Production or purchase
   b. Season of use
4. Public-land allotment use
   a. Boundary lines
   b. Seasonal units

C. Cooperative relationships
1. Associations
2. Cooperative marketing
3. Advisory boards
4. Provision for interrelated demands upon land

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CHAPTER 13

SECURING PROPER RANGE USE

Maximum production from a given range unit is dependent upon proper management and use of the resources. Of fundamental importance are (*a*) balancing numbers of animals with forage resources, (*b*) grazing at the correct season of year, and (*c*) securing proper distribution of livestock over the range.

IMPORTANCE OF CORRECT LIVESTOCK NUMBERS

Correct numbers are important for the perpetuation of the range, the well-being of the livestock, and the economic stability of the operator. Continued overoptimism regarding the capacity of range land is certain to result in a failure of the livestock enterprise and impaired land values. Grazing-land values generally are proportionate to the expected annual returns of meat and wool. When overuse takes place, the forage cover is reduced and less meat and wool are produced from an acre, reducing the capital value of the land. Such declines in income and ranch value cannot be permitted if the operation is to be conducted on a permanent basis.

Often the livestock operator places too much importance upon numbers and not enough upon livestock quality and care in management.

Chapter 4 has discussed the dangers of overgrazing to the physiological functions of the plant. Chapter 5 pointed out how misuse introduces unfavorable succession in the plant community. Chapter 7 explains some of the difficulties in determining correct grazing capacity of range land. Unfortunately, range forage can be neither weighed nor measured accurately. Unlike hay and grain, range forage cannot be used in its entirety. When the haystack is gone, the farmer knows he must provide other forage. When the harvestable portion of the range forage is gone, however, there is a residue that must be left if the range is to continue normal production. If forced by economic emergency, drought, or sometimes by mere ignorance or greed of their manager, livestock can survive for a long time and in apparent good health on this residue. It is unfortunate that there exists no accurate measuring stick for determining full range use. Good judgment on the part of the experienced manager is the best practical measure.

Most ranchers understand that ranges are harmed by misuse, but some do not understand how directly this affects their income. That they do not practice better management is attributable to insufficient understanding of the problems confronting them. Range management is a business of no mean complexity. Often, its intricacies are secondary in the minds of men more concerned with meeting bills and paying taxes. Management suggestions must be coldly practical and economically sound to be acceptable. The technical adviser should not become so obsessed with the desire to improve range conditions that he loses sight of the economic limitations to range-management theory. Nor should the rancher be so concerned with immediate income that he loses sight of the far-reaching influence of good husbandry upon his economic welfare.

In a business largely controlled by economic necessity, any management practice must pay its way if it is to be acceptable. Fortunately, the objectives of sound range management can be made consonant with the more impelling economic forces. In no other way can good management be generally acceptable. If it is not economically sound, there is need for improvement in the practice or for reordering of the economic structure so that ranchers can adopt what to them, all too often, seem highly theoretical objectives.

Influence of Numbers upon Range Production. Proper grazing has an important bearing upon the success of the ranching business. Through improved grazing management, the calf and lamb crop may be increased, the death loss minimized, more livestock produced and marketed, and animals sold at higher price. Good range conditions increase the number of calves and lambs produced, presumably a direct result of the superior vigor of the animals (see pages 286–288). High calf and lamb percentage likely is the most reliable index to success of a commercial breeding-livestock operation. By maintaining animals in better vigor, they are more able to withstand the vicissitudes of bad weather, diseases, and other adverse factors to which they are subjected, hence death loss is decreased.

Another factor of great importance to the economy of the ranching business is the amount of beef or mutton that can be produced for market under good range management. Experiments in North Dakota on grama-wheatgrass-needlegrass range show a close relationship between gains per animal and acreage of range allotted to each animal (Table 54). Greater per-acre gains, however, were made with more intense stocking.

The 7-acre stocking was considered correct and vegetation did not decline. At 5-acre stocking overgrazing was apparent, but the range could be restored by proper care and management. The 3-acre range was severely overgrazed and many choice species disappeared, and unpalatable weeds as *Artemisia frigida* increased. This range, also, was unable to

support the animals for the full 5-month grazing season. Many years would be required to restore the range condition to normal (34).

Hereford cows grazed on Montana short-grass ranges at the rates of 23.1, 30.5, and 38.8 acres per cow-year produced over a 12-year period an average weaned-calf weight per cow of 279, 322, and 327 lb., respectively (16).

TABLE 54 RATES OF STOCKING, GAIN PER HEAD, AND GAIN PER ACRE OF STEERS GRAZED ON NATIVE PASTURES, AVERAGES FOR 20 YEARS
Data from Sarvis (34)

Acres per head, 5-month season	Seasonal gain per head, pounds	Seasonal gains per acre, pound
10	311	31
7	308	44
5	234	47
3	160	53

Cows were grazed on California annual-grass foothill ranges for a 6-month season at rates of about 10, 15, and 20 acres per head during 11 years (4). Cows gained 143, 224, and 240 lb. and weaning weights of calves were 378, 432, and 450 lb., respectively. The heavy grazing initiated undesirable changes in vegetation composition and some soil deterioration. The moderate grazing rate was considered best.

Open pine ranges in central Colorado mountains were grazed by yearling Hereford heifers from June 1 to October 31 for a 6-year period at three intensities giving utilizations of 10 to 20 per cent, 20 to 40 per cent, and 50 per cent or more respectively (21). Average gains were 236, 222, and 181 lb. per head and 8.5, 16.0, and 14.8 lb. per acre, respectively. Utilization of 35 to 40 per cent was considered best. Heavy grazing lowered forage production and vigor of grass, initiated unfavorable plant succession, and reduced income (Table 55).

On mixed prairie vegetation in South Dakota, Hereford cows were grazed during the 7 summer months for a 5-year period at rates as follows: light, 3.1 acres per head per month; moderate, 2.3 acres; and heavy, 1.4 acres. Average utilization of forage was 29, 34, and 54 per cent, respectively. For the following three years, acres per head was decreased to 2.5, 1.8, and 1.1 to give utilizations of 48, 60, and 74 per cent, respectively (20). In the first five years, average fall cow weights were 997, 939, and 950 lb. and in the subsequent 3-year period weights were 976, 902, and 845 lb., respectively. Calf weights at weaning were 387, 375, and 361 lb. in the first period and 375, 354, and 349 lb. in the second. An annual removal of 40 to 50 per cent of the foliage, or about

2.25 acres per animal unit month, was considered ideal. Range condition was markedly reduced under heavier use and herbage production was 10 to 31 per cent less than under moderate grazing.

Hereford steers were grazed yearlong at three rates of stocking in the southern Great Plains in Oklahoma for 10 years. Animals were allowed 6.5, 9.7, and 12.9 acres per head and gained an average of 361, 384, and 400 lb., respectively, per head (25). Per-acre gains, however, were 56, 40, and 31 lb., giving per-acre profit of $6.46, $4.52, and $3.36 in favor of heavy stocking. Although slight detrimental vegetation change occurred under heavy grazing, it was not serious and the pastures were not considered overgrazed.

TABLE 55. PRODUCTION AND ESTIMATED RETURN PER SECTION FROM PINE-BUNCHGRASS RANGE IN COLORADO GRAZED AT THREE INTENSITIES, 1946–1947

Data from Johnson (21)

	Heavy grazing	Moderate grazing	Light grazing
Animals per section	53	47	27
Gain per head (5 months), pounds	172	211	231
Gross return per section, dollars	661	1,027	724
Costs (death loss, grazing fee,* interest, etc.), dollars	188	163	97
Net return per section, dollars	473	864	627

* Land costs used were the cost of standard Forest Service fees. This results in the same cost per head regardless of stocking intensity. Actually, of course, the landowner by heavy stocking reduces the forage cost per head since interest and taxes chargeable to land are independent of stocking intensity.

On an experimental range of salt-desert vegetation in Utah (18), sheep were grazed over an 11-year period for about 5 winter months at two intensities. Moderately grazed range was stocked at 15 sheep-days per acre and the heavily grazed range was grazed about one-fourth heavier. Ewes under moderate grazing weighed 4 to 18 lb. more than those under heavy grazing at the end of the season. They produced about 1 lb. more wool, 11 per cent higher lamb crop, and $1.77 higher income per head.[1] The moderate stocking resulted in improved range condition and increased herbage production.

Economic Considerations. The many experiments on intensity of grazing are all inconclusive, because they do not sample sufficient levels of

[1] Land costs used were the cost of public-land grazing fees. This results in the same cost per head regardless of stocking intensity. Actually the private-land operator's forage costs per head do not increase proportionately to the number of animals since land costs remain constant with heavy stocking, and only those costs attributable to livestock increase.

grazing intensity, they are not continued long enough to determine vegetation and soil responses, and they are not analyzed in terms of true economic effect upon the operator or sociological effect upon the nation. For immediate maximum production of meat and wool, and hence profit, heavy grazing surely is essential. Overgrazing, however, will result in reduced herbage production and hence lower profit if continued indefinitely. An individual may benefit from deliberate overgrazing to secure quick income, provided the land will respond rapidly to good management following overgrazing. Furthermore, he may secure enough income to pay back the investment in land plus some additional for profit. By thus *mining* the land, he is ahead, even though his ruined range must be resold for literally nothing. If soil is not eroded by misuse, artificial seeding may bring the land back to original productivity at a cost payable from the increased profit. Of course, the social hazard of deliberate misuse of land, especially if it results in land abandonment or expensive publicly financed reclamation projects, should not be ignored.[1]

Conversely, very light grazing, to give maximum yield per animal, may be below the economically practical level. Probably correct range use lies somewhere between maximum production per animal and maximum immediate return per acre.

Over a long-time period conservative stocking will pay dividends. When the cost of (*a*) extra investment in animals and the accompanying extra work, extra salt, and extra equipment, (*b*) reduced calf or lamb crops, (*c*) reduced gains, (*d*) reduced price per pound for poorer stock, and (*e*) increased supplemental feed are considered and weighed against the cost of more land to supply needed forage, the rancher can appreciate that overstocking does not make for high income on a sustained basis. It not only decreases the meat yield but ultimately it greatly injures the range land. For additional data on factors affecting calf and lamb crops see Chapter 12, pages 288–290.

Forage Quality. Factors contributing to decreased production under heavy grazing are reduced quantity and reduced nutritive quality accompanying close use. Pasture studies (22) have shown that on dense stands of forage (1,000 lb. dry matter per acre), cattle ate 32 lb. of dry matter per day; with continued grazing and decrease in forage (500 lb. per acre), consumption decreased to 20 lb.; with further grazing (250 lb. per acre), consumption reached only 10 lb. per day.

Experiments with sheep on salt-desert ranges in Utah (7) showed that continued grazing during the nongrowing season resulted in progressive decline in nutritive value of forage consumed (Table 56).

[1] For a discussion of the economics of conservation, the reader is referred to Resource Conservation Economics and Policy, by S. V. Ciriacy-Wantrup, University of California Press, Berkeley. 1952.

TABLE 56. EFFECT OF INTENSITY OF UTILIZATION UPON CHEMICAL COMPOSITION OF THE DIET AND DIGESTIBILITY OF NUTRIENTS ON BLACK SAGE (*Artemisia nova*) RANGE WHEN GRAZED BY SHEEP

Data from Cook and Stoddart (7)

Utilization, per cent	Dry matter consumed per day, pounds	Total protein, per cent	Protein digestibility, per cent	Cellulose, per cent	Cellulose digestibility, per cent	Other carbohydrates, per cent	Other carbohydrates digestibility, per cent	Gross energy, cal./kg.	Gross energy digestibility, per cent	Phosphorus, per cent	Total digestible nutrients, per cent
0–30	2.9	8.5	54.5	25.6	35.9	33.9	58.2	5,172	43.6	0.16	48.3
31–55	2.4	7.8	53.9	23.7	24.5	33.7	55.3	4,977	35.9	0.12	39.3

INDICATORS OF PROPER LIVESTOCK NUMBERS

Although long-time production records are indexes to correctness of range stocking, the examiner may not have access to such records and must rely on range condition and indicators. Deteriorated range conditions may precede reduced livestock production, hence unsatisfactory situations may be discovered by careful ecological study before production is seriously impaired.

The use of vegetation as an indicator is based upon the ecological premise that vegetation is the product of its environment; hence the product can be used as an indicator of the causal relationships. Unsatisfactory range condition may result from habitat factors other than the biological factor of grazing. Drought and fire, especially, should be studied as causative factors. Much confusion has resulted from interpreting degeneration from drought to be a result of excess grazing. Erosion resulting from abnormal weather conditions often erroneously is attributed to mismanagement. Many of the so-called grazing indicators, unless carefully qualified, are in reality indicative merely of poor growing conditions or unusual disturbances from any cause. Poor soil may support weedy species or stunted species that superficially appear to be misused.

The use of plants as indicators is not confined to plant occurrence as a measuring stick; rather, it involves plant condition as well. The mere occurrence of a species need not indicate conditions suitable to that species, for dwarfed and sickly specimens exist for years in a habitat distinctly unfavorable for optimum growth and development.

Before a decision is made, it is desirable to learn all that is possible of the history of settlement, cultivation, and grazing. It is important to know the climate, recent weather conditions, and normal vegetation. It is well to remember that an indicator is only an indicator and that one,

alone, may be unreliable. All possible clues should be considered. The use of plants as range-condition indicators is discussed in detail on pages 119–125 and 179–181.

The most accurate indexes of overgrazing are the early changes that take place in the vegetation as a result of plant succession. Grazing gradually reduces the more desirable plants and makes available soil nutrients and moisture for less desirable plants. The result is a change in the composition (Fig. 105). Early recognition of such changes is of the greatest value in determining the adequacy of existing management.

Fig. 105. A short-grass range which is badly invaded by cactus (*Opuntia*) as a result of heavy grazing. In such large quantities, this plant is a reliable indicator of misuse. (*Photograph by J. E. Weaver.*)

Just as it is important to the physician to recognize and diagnose disease before it has progressed so far that recovery is impossible, so it is important to the range manager and rancher to recognize range ills in their developmental stage.

The palatable shrubs can be used as a guide to range use. The presence of dead stubs of browse and a hedged appearance warn the observant stockman that grazing should be decreased. When stock nip off the tip of a branch, further growth must be from lateral buds. Frequent grazing results in excess branching, which is an easily recognized sign of overgrazing (Fig. 39).

Plants Commonly Indicating Heavy Grazing. A general abundance of plants that are not preferred by livestock indicates heavy use of the range.

Some plants that in large quantities ordinarily indicate misuse of the range are: sneezeweed (*Helenium hoopesii*), gumweed (*Grindelia squarrosa*), snakeweed (*Gutierrezia sarothrae*), houndstongue (*Cynoglossum* spp.), rabbitbrush (*Chrysothamnus* spp.), cactus (*Opuntia* spp.), bullthistle (*Cirsium* spp.), Russian thistle (*Salsola kali tenuifolia*), loco (*Astragalus* spp.), death camas (*Zygadenus* spp.), horsebrush (*Tetradymia* spp.), dock (*Rumex* spp.), mule ear (*Wyethia* spp.), foxtail (*Hordeum jubatum* and *H. pusillum*), peppergrass (*Lepidium* spp.), lamb's-quarters (*Chenopodium* spp.), niggerhead (*Rudbeckia* spp.), sunflower (*Helianthus* spp.), pigweed (*Amaranthus* spp.), pricklepoppy (*Argemone* spp.), burroweed (*Aplopappus tenuisectus*), rubberweed (*Actinea* spp.), threeawn grass (*Aristida* spp.), burrograss (*Scleropogon brevifolius*), fluffgrass (*Tridens pulchellus*), ring muhly (*Muhlenbergia torreyi*), mat grama (*Bouteloua simplex*), six-weeks dropseed (*Sporobolus minutissima*), false buffalo grass (*Munroa squarrosa*), six-weeks fescue (*Festuca* spp.), wild daisy (*Erigeron* spp.), collomia (*Collomia* spp.), knotweed (*Polygonum* spp.), beeflower (*Cleome* spp.), toadflax (*Linaria* spp.), stickseed (*Lappula* spp.), tarweed (*Madia* spp.), wild tobacco (*Nicotiana* spp.), bur sage (*Franseria deltoidea*), baby breath (*Gayophytum* spp.), pentstemon (*Pentstemon* spp.), phacelia (*Phacelia* spp.), plantain (*Plantago* spp.), butterweed (*Senecio* spp.), goldenrod (*Solidago* spp.), nettle (*Urtica* spp.), mullein (*Verbascum* spp.), wild buckwheat (*Eriogonum* spp.), western false hellebore (*Veratrum californicum*), tarweed (*Hemizonia kelloggii*), turkey mullein (*Eremocarpus setigerus*), foxtail chess (*Bromus rubens*), fringed sage (*Artemisia frigida*), buttercup (*Ranunculus* spp.), golden aster (*Chrysopsis villosa*), sand sage (*Artemisia filifolia*), cryptantha (*Cryptantha crassisepala*), cinquefoil (*Potentilla* spp.), creosotebush (*Larrea divaricata*), Kentucky bluegrass (*Poa pratensis*), and dandelion (*Taraxacum* spp.).

Disturbances Indicating Heavy Grazing. Many indicators of the past use of range land are associated with disturbance of the soil. Soil changes, like vegetation changes, should be recognized early, for by the time that they are obvious, much damage has been done. That concentrations of animals can have a profound effect upon soil is evident from terracing of steep slopes by animals moving constantly back and forth (Fig. 106). This may be so severe as to utilize a major part of the area in trails.

Removal of soil from range lands by wind or water is an index of the severity of use in the past. Where water has been the eroding agent, gullies are usually present, though considerable sheet erosion may take place before gullies are formed. On the steep topography characteristic of much of the West, gullies ordinarily appear soon after erosion becomes excessive and are valuable indicators of too heavy grazing. Aside from their abundance, much can be learned from the appearance and condition of

the gully. When freshly cut, the banks tend to be vertical and devoid of vegetation. Because soil normally will not stand at such an angle, the banks begin to slough off. If the gullies have sloping banks upon which vegetation is beginning to grow, it is usually evidence that erosion is decreasing.

Wind, as it moves across a range, picks up the smaller particles, whereas the larger-sized particles are moved along the surface of the ground and pile up in dunes. This usually leaves islands of soil underneath vegetation where the roots of the plants hold back soil against the wind (Fig. 107).

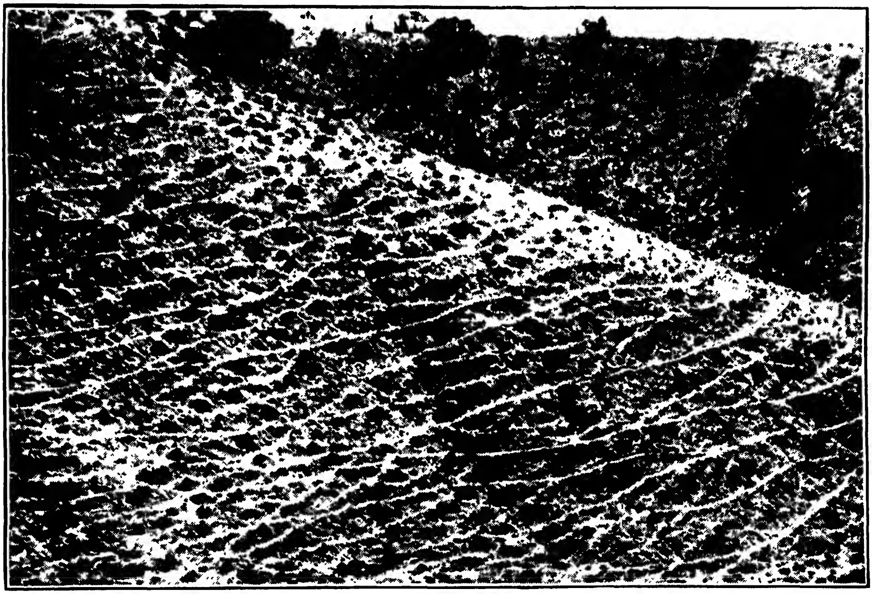

FIG. 106. Evident terracing of a hillside resulting from trampling by livestock. Such trails may be of some value in impeding the flow of runoff water, but the soil is generally too compacted to absorb water readily.

The amount of soil removal is indicated by the height of these islands, though sometimes the soil also accumulates around the plants as a result of soil deposition. The presence of hummocks and sand dunes generally is indicative that soil is being removed and that grazing is excessive (Fig. 86, page 230). For a more detailed discussion of soil depletion see page 187 and pages 220–231.

Livestock Condition as Grazing Indicator. If their animals are vigorous and thrifty, stockmen sometimes consider range condition to be satisfactory. Research has shown, however, that range deterioration may progress for considerable time before the change is reflected in livestock condition. Forage condition is a more sensitive indicator.

Use of forage condition as the criterion of proper grazing does not imply that meat production is ignored. Continued and dependable income is contingent upon maintaining the forage production at its maximum. The production of meat is the goal of range management; forage production is not an end in itself. Unfortunately we do not yet have accurate information concerning the relation between maximum meat production and forage conservation. This subject is discussed further on pages 306–309.

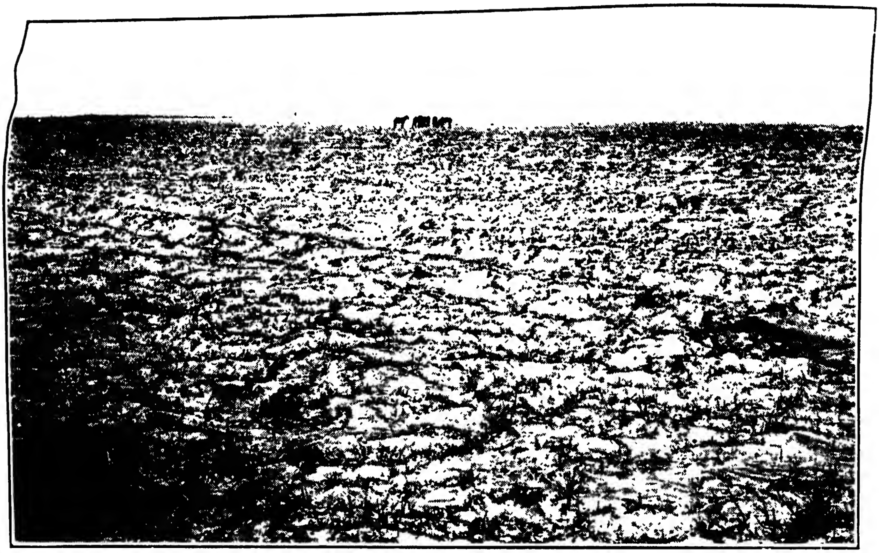

FIG. 107. A Texas range which has been severly damaged by wind erosion and is rapidly approaching complete denudation. (*Courtesy of U.S. Soil Conservation Service.*)

EFFECT OF WEATHER UPON GRAZING CAPACITY

There is a close relationship between forage production and climate, particularly precipitation. Precipitation in the West is unusually low and undependable, and periods of low precipitation often are protracted (Chap. 2). Subnormal rainfall usually is accompanied by a decrease in forage production. On the Snake River Plains of southern Idaho, between 1932 and 1935, total vegetation on ungrazed areas decreased to 84 per cent of the 1932 ground cover, grasses alone decreasing to only 48 per cent of the 1932 cover (29). In the Southwest, over a 13-year period during which two drought periods were experienced, one lasting for 3 years and the other for 5 years, the cover of black grama (*Bouteloua eriopoda*) decreased to a low point of 10.9 per cent of the original, even though ungrazed (27). This marked reduction in forage yield resulting from poor growing conditions alone makes it evident that no plans for grazing

should be made without allowing for variation in production attributable to weather conditions. In the above instances, grazing did not influence the decline in production (Fig. 108).

Studies on salt-desert range in Utah show remarkable correlation between forage production and precipitation (Fig. 109). Expected air-dry herbage yield in pounds per acre can be calculated with considerable accuracy in this area by multiplying 12-month precipitation in inches by 45.8 and subtracting 92.46 (18).

FIG. 108. A well-managed pasture in eastern Colorado showing the open cover of short grass resulting from drought. No amount of good management can prevent damage from drought.

Drought damage to plants is affected materially by grazing use. Studies indicate that conservative grazing is little or no more harmful than is total protection (10, 27, 36). Under heavy grazing, however, plants suffer great damage and are more susceptible to drought injury. On the Snake River Plains, depletion of spring-fall ranges during drought periods was found to be proportional to the degree of grazing during the spring (10). Similarly, decreases in production of the principal grasses of the Great Plains under drought conditions were found to be directly proportional to the intensity of grazing (36). The reason for the relationship between grazing and drought is that heavy grazing decreases both the depth to which roots penetrate and the volume of root production.

Utilization to Prevent Damage to Plants during Drought. Variable production of forage must be anticipated in the management plan. Even under conservative stocking based upon average production, certain

subnormal years may be expected during which forage shortages will occur. When livestock numbers cannot be varied, the stocking level must be based upon average forage production. Usually 65 to 80 per cent of average forage production is a safe base for calculating grazing capacity (Fig. 110). Under no plan of stocking at a constant level will it be possible to prevent excess use in poor years and under use in good years. Forage remaining in years of high production is not wasted, for it adds to the vigor of the plants, permitting them to recover better from close use during poor years.

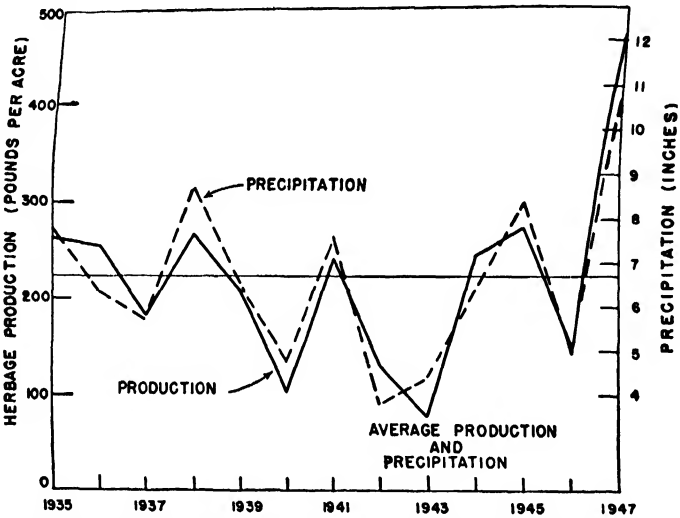

FIG. 109. Average herbage production measured in October as correlated with precipitation during the preceding 12-month period at the U.S. Forest Service Desert Experimental Range, a salt-desert winter sheep range located in southwestern Utah. See also Fig. 5, page 22. [*After Hutchings and Stewart* (18).]

Adjusting a livestock program to adapt it to varying forage production is of great importance. Most ranchers find it difficult to vary numbers to balance stocking against the whims of the weather. In years of abundant forage, it is difficult to purchase livestock because of the demand from other producers. In poor years, the flood of animals on the market makes selling prices low. An attempt to regulate numbers according to range production by a buying and selling program is hazardous. The producer is tempted to hold over high numbers during poor years in a play for better markets. Severe overuse of the range, already weakened by drought, is likely to be the result.

Grazing studies (24) have showed range-capacity variations in central New Mexico from 63 per cent above to 61 per cent below normal and suggested consideration of the following means of adjusting the livestock program to fit such conditions.

To decrease the herd during below-normal periods: (*a*) sell early enough to ensure sufficient feed to carry the breeding herd, (*b*) sell cattle whose meat value is near maximum, such as fat-dry cows and calves of acceptable market age, (*c*) sell weaned calves and old or thin cows which would be expensive to carry over, (*d*) sell heifers that would not contribute to building up the herd, and (*e*) sell inferior or nonbreeding cows.

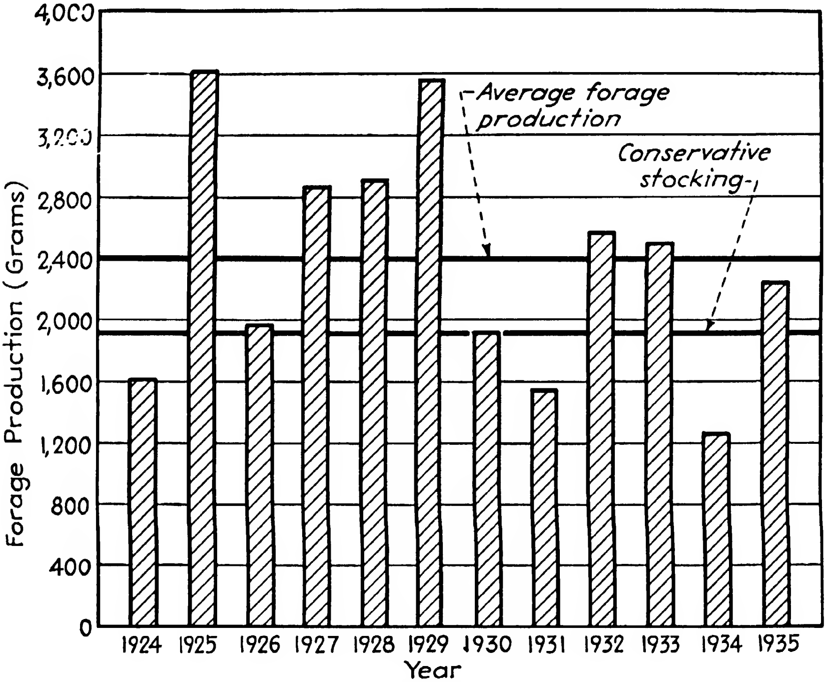

FIG. 110. Production of mixed perennial grasses in central Utah fluctuates greatly from year to year, and conservative stocking must be 20 per cent or more below average production to furnish adequate forage in all but the lowest years. (*From R. S. Campbell, Climatic fluctuations. In U.S. Department of Agriculture, Forest Service, The western range. U.S. Congress 74th, 2d Session, Senate Doc. 199, pp. 135–150. 1936.*)

To increase the herd during above-normal periods: (*a*) keep steer calves another year, and (*b*) increase the cow herd by retaining heifers or buying.

Compensating for variability of range feed by the use of supplemental forage or adjusting length of grazing season offers a more practical method of management in most areas than does adjusting livestock numbers.

IMPORTANCE OF SEASON OF GRAZING

Chapter 4 described the effects of season of grazing upon the physiological welfare of the plant. It is known that an animal unit month of

grazing may affect the range quite differently dependent upon season of the year.

Although some operators buy steers and graze them only for a part of the year, 12 months of feed are required in most ranch operations. Part of this may be secured from farm fields, cultivated pastures, and feed lots. It is now rare that animals spend 12 months on the range. Even these may receive supplemental forage which is hauled to them.

Animals grazing for 12 months may remain on the same area as a *yearlong range*. This is common in the southern portions of the West. On more northerly ranges, animals customarily move from one to another of various *seasonal ranges*. This seasonal migration is regulated by many factors, such as snow, quantity of forage, quantity of water, condition of stock, loss of nutriment in drying forage, growth stage of spring forage plants, soil-moisture conditions, and, occasionally, insects or parasites. The seasonal use often is not obligatory but merely convenient.

In northern areas, snow prohibits winter grazing on ranges of high elevation. The summer grazing season varies from north to south, but on an average it is about 4 months long and includes the months of June, July, August, and September. During December, January, February, and March, grazing is confined to ranges of lower elevation. These winter ranges are usable throughout most winters because low precipitation inherent to low-elevation valleys and plains of the West results in comparatively light snowfall.

The winter grazing season generally starts when animals are forced by snow from the fall ranges and ends when shortage of water forces the animals to leave or when the beginning of plant growth in the spring or shortage of feed makes further use unwise. The fall season occupies the months of October and November, and the spring season the months of April and May. Often, the same area is used as a *spring-fall range*, this being the foothill ranges of intermediate elevation. There exist, also, a few areas in which, because of the concentration of moisture in the summer and freedom from snow in the winter, animals are grazed on the drier low-elevation ranges in the summer and on the moister high-elevation ranges in the winter.

Spring grazing generally commences when soil is firm after winter snow and when plants have had opportunity to make good growth. This is known as the period of *range readiness*. Rapid growth of plants in spring may temporarily deplete food reserves (Fig. 41, page 102). Deferring grazing until the plant has had opportunity to restore these food supplies is advisable.

Examples of plants that bloom before grazing should begin are steerhead (*Dicentra uniflora*), dogtooth violet (*Erythronium grandiflorum*), spring beauty (*Claytonia lanceolata*), waterleaf (*Hydrophyllum capitatum*),

smooth buttercup (*Ranunculus glaberrimus*), trail potato (*Orogenia linearifolia*), newberry bladderpod (*Physaria newberryi*), and tongue-leaf violet (*Viola linguaefolia*). These generally are unimportant from the standpoint of production of forage, but they are useful as indicators of the stage of forage growth (33).

The proper time for grazing also may be based upon forage grasses. Early-maturing species such as mountain Junegrass (*Koeleria cristata*), Fendler and Sandberg bluegrasses (*Poa fendleriana* and *P. secunda*), and downy bromegrass (*Bromus tectorum*) usually will have started to produce flower heads by the time stock should go on the range. Grasses that mature later, such as wheatgrasses (*Agropyron* spp.), bromegrasses (*Bromus* spp.), and needlegrasses (*Stipa* spp.), will not have shown any flower heads, but the foliage will usually have reached a height of 6 or more inches.

Where the majority of the forage is made up of browse, these plants should be observed closely. Usually the main browse species will have leaves that are one-half to three-fourths developed by the time the grazing should begin. Chokecherry, serviceberry, deerbrush, bitterbrush, and whitethorn will have started blossoming.

Range-readiness problems are quite distinct on ranges where annual plants are the major forage species. Here, heavy use during the growing season is the usual practice. Most annuals, even under heavy use, are able to produce sufficient seed to ensure a subsequent crop.

Variation in Date of Readiness. There are great differences from year to year in the time at which comparable growth conditions are reached. The same phenological stages varied as much as 47 days from year to year in central Utah (8), and in southeastern Idaho the date of beginning of growth of the most important grass varied from March 20 to April 24 during a 9-year period. This is of great importance to the rancher, for he must feed livestock for a much longer period in extremely late years. There is indication that the time of readiness might be predicted as much as 3 months in advance of the opening date for grazing by the rate of disappearance of snow.

Altitude also affects rate of vegetation development. Most observers agree that the difference approaches one day for each 100 ft. of altitude. Also, a given stage of vegetation development is about 4 days later as one progresses northward 1 degree of latitude (14).

Loss of Nutrient from Too Late Grazing. Plants, especially herbaceous species, as they pass maturity lose much of their succulence, decrease in digestibility, become less nutritious, and are less palatable to animals. The degree of these changes depends upon the species. Frequently, much of the forage cannot be harvested if the season is delayed unreasonably. Mature grass, for example, may be almost unused by sheep.

Numerous chemical and digestibility studies show quality of forage to decrease as it matures. It is not only less digestible but contains less protein, vitamins, and phosphorus, and more lignin and fiber. Other studies have shown that without exception animal gains decrease as maturing vegetation becomes less palatable and nutritious. Of course, animals are usually thin when they are placed on green forage in spring and hence naturally gain fast. But, eliminating this factor of animal condition, early season still is the time of greatest animal gains (see Table 57).

TABLE 57. DAILY GAINS OF LIVESTOCK IN POUNDS PER HEAD, SHOWING EFFECT OF SEASON. ANIMALS ARE ALL OF HEREFORD BREED EXCEPT AS DESIGNATED

Cattle and location	May	June	July	August	September	October
Steers, Oklahoma prairie (25)	2.0	2.0	1.8	1.4	1.0	1.0
Large steers, Utah mountains (38)	...	...	2.16	1.92	1.11	0.68
Small steers, Utah mountains (38)	...	...	1.96	1.93	1.31	0.91
Two-year-old steers, N. Dakota plains (34)	1.2	3.5	2.3	1.8	1.3	0.0
Yearling steers, N. Dakota plains (34)	4.0	2.3	1.7	1.6	1.0	0.7
Heifers, Colorado mountains (21)	...	2.49	1.74	1.50	1.37	−0.03
Holstein Heifers, Utah mountains (38)	...	...	1.03	1.57	1.02	0.59
Cows, S. Dakota plains (20)	2.6	1.8	1.0	−0.1	−0.7	−2.2
Calves, S. Dakota plains (20)	1.5	1.5	1.7	1.8	1.5	0.9
Cows, Utah mountains	...	1.7	2.0	1.2	0.9	−0.2
Calves, Utah mountains	...	1.5	1.6	1.5	1.9	0.8
Cows, Colorado plains (23)	1.7	1.9	1.6	0.0	−0.2	−1.2
Calves, Colorado plains (23)	1.7	1.7	2.0	2.0	1.7	1.0

Losses from delay in grazing are especially great in annual-plant types. Although they are occasionally palatable and nutritious while green, most annuals do not cure well and hence may become almost valueless if livestock are not allowed to graze them early. Perennial forage plants on the western range are much less subject to loss. Shrubs and some grasses cure well and, even when dry, are relished by livestock. Browse plants store much of their nutriment in the stems, which are consumed by grazing animals, and maturity detracts but little from their grazing value. Most forbs do not cure well, but few being valuable as forage after maturity. See also *Effects of Season upon Forage Value,* page 268.

In the mountain and intermountain sections of the West, the spring and fall range is the most difficult to fit into the grazing system. Expansive

valleys and plains provide winter grazing, or stock are wintered on harvested feeds. If the ranch is one upon which winter feeding is practiced, economic pressure encourages use of the ranges at the earliest possible time, for feeding is more costly. Under such circumstances it is natural that the rancher desires to get onto the range as quickly as possible. However, winter ranges are almost always at lower elevations, hence, plant growth begins earlier than on spring ranges, and spring range is not ready to graze as early as animals must leave winter range.

A general criticism might be made of federal range administration in that the custom has been to make reductions in grazing intensity by shortening season of use rather than reducing numbers. Although benefit to the public range is attained with apparently less hardship to stockmen, the result generally has been that the stockmen have to find additional range or farm feed. Where this feed is not readily available, misuse of the private range is encouraged. Further, a short grazing season results in overuse of plants palatable during that season and they are replaced by species less desirable at that particular period. Such *seasonal overgrazing* may reduce grazing value, even though density and apparent quality are maintained.

FEEDING AS A MEANS TOWARD PROPER GRAZING

Feeding harvested crops in the feed lot or on the range and foraging on cultivated pastures offer major opportunities to improve range management. Three factors which make necessary an adjustable feeding program as a part of western livestock production are (*a*) great annual variation in forage production from year to year, (*b*) lack of balance between seasonal classes of range, and (*c*) frequency of heavy snows in some regions, which prohibits winter grazing. In order to adjust a ranching enterprise to fit the varying conditions brought about by these factors, a flexible plan of providing supplements should be considered. Failure to do this has been responsible in the past for much overuse and seasonal misuse of the range and considerable loss in monetary returns.

The possibilities for profit on ranges that can be grazed yearlong have been estimated (35) to be about twice as great as on ranges that require a long period of winter maintenance on hay, although much of this difference is absorbed by higher land prices on yearlong ranges. But despite the fact that range forage is the cheapest livestock feed, ranchers should not consider other sources of feed as emergency measures only. Frequently, ranchers maintain animals on a range long after suitable forage is gone. Not only would the provision of supplemental feeds prevent serious damage to the range, but the monetary returns might be greatly increased as well. It is obviously poor management and poor

economy to misuse range forage in order to avoid expensive supplements.

Many western areas show a sharp increase in hay acreage since 1920, and it appears probable that in many localities the average length of the period of winter maintenance on hay has increased by 4 to 6 weeks (35). Although holding over supplemental feeds to care for animals during feed shortages requires foresight and careful analyses of range use each year, it is important to do so. Attention to details and the ability to alter plans to fit conditions rather than blindly following the same procedure year after year are the marks of progressive and successful stockmen.

Emergency Planting. Much can be done to increase feed for livestock during emergency periods and early spring by planting of such crops as Sudan grass, winter rye, and oats. These annuals give heavy yields, are well liked by livestock, are easily grown, and produce usable forage within a few weeks of planting. The great advantage of such crops is their flexibility. They can be produced as the need is foreseen and can be omitted during years of good range production. Although perennial grasses generally are more satisfactory, annual grains, especially winter rye, volunteer readily and, even though closely grazed, may persist for many years without reseeding.

Spring Pastures. Early spring is a critical period for western ranges. During this season of scarce forage, farm feeding is common, but harvested feed is costly compared with pasturage. Great strides toward a self-sustaining and balanced range production have been made by developing pastures on the farm. As the carrying capacity of western range land becomes reduced and the seasonal shortages become more apparent, more livestock are kept on the farm for at least part of the year. Unfortunately, farm pastures in the West are of surprisingly low productivity, many being little better than are adjacent range lands. The reasons are manyfold, but perhaps the most important contributing factors are as follows: (*a*) The pasture land of a farm is often the leftover land or land that is least productive. (*b*) Many pastures are natural meadows that have been run down by misuse until they produce nothing but native grasses or grasslike plants of relatively low productivity and nutritiousness. (*c*) Pastures are frequently overused and are expected to accommodate all extra animals that happen to be on the farm. (*d*) Since returns from pasture are seldom cash returns, they are not measured or appreciated; hence, no money or time is spent on fertilizing, draining, or otherwise caring for the pastures. (*e*) Pasture plants are more drought-resistant than other farm crops, hence the pasture is deprived of irrigation water during times of shortage, many pastures receiving nothing except early-spring floodwaters.

Intensive management of pasture land, including, where necessary, seeding to cultivated grasses and clovers, fertilizing, draining, irrigating,

and rotation grazing, results in high yields. Production in excess of 5,000 lb. of total digestible nutrients per acre or about 300 cow-days grazing per acre are entirely possible (Fig. 111). Utah pastures have produced over a period of 7 years a return of more than $250 per acre when grazed by dairy cows (3). Under intensive management by strip rotation on a 24-hour rotation plan, 20 acres of pasture furnished forage for 36 cows for 4½ months. No other crop was able to equal this production and income.

An acre of good pasture has been shown to carry 8 to 10 sheep for the summer, and 12 to 15 acres of good irrigated pasture and 6 to 10 acres

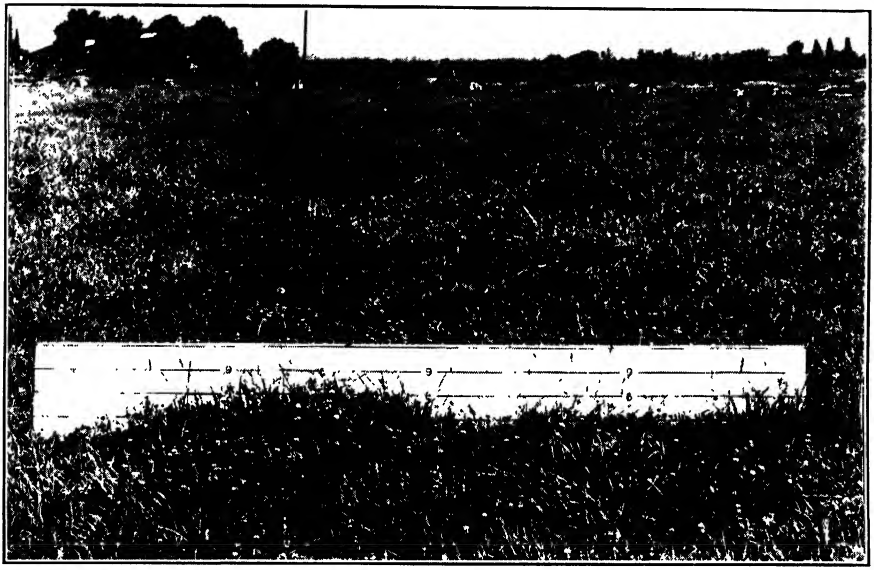

FIG. 111. This excellent irrigated pasture in northern Utah is fertilized with manure and commercial superphosphate and is grazed under a system of short rotation, the grasses being allowed to reach a height of 3 to 6 inches before grazing. Handled in this way, such pasture will supply more forage than will any other crop. (*Photograph by G. Q. Bateman.*)

of hay land will keep 100 ewes and lambs throughout the year (11). Considering feed cost, investment in materials and land, mutton and wool yield, losses from poisonous plants and predators, and all other measurable factors, sheep flocks spending the entire year on the farm showed returns equivalent to those of flocks grazed on national forest ranges.

EFFECT OF DISTRIBUTION UPON GRAZING CAPACITY

Overgrazing on a range is not dependent entirely upon the number of animals; all the attendant results can be realized locally if stock are not distributed properly. Animals naturally congregate at certain points. On

cattle range, the most accessible areas such as valley bottoms (Fig. 112), low saddles between drainages, areas around water holes, and level mesas are first utilized. Steep areas and areas far from water are less well utilized or even unutilized. In some areas steep slopes are unable to stand heavy use, whereas valley bottoms are less injured by concentrated grazing (13). Therefore, this habit of cattle may not be altogether undesirable. Unherded sheep will overutilize ridge tops, where they return each night to bed. Many apparently overstocked ranges will be able to

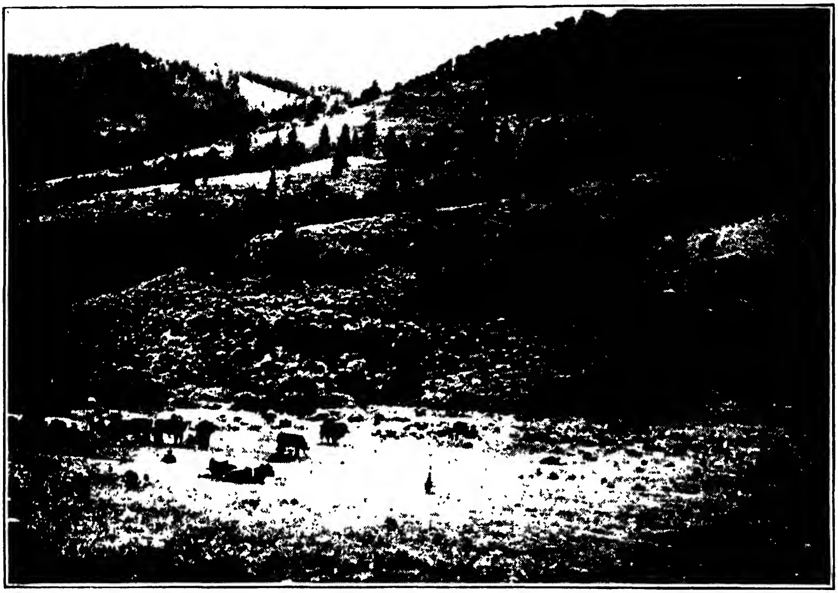

FIG. 112. Cattle normally tend to congregate on meadows and along stream bottoms, especially in the fall. Obtaining good distribution through fencing, herding, or salting is an important problem of range management and is essential in avoiding local overgrazing.

improve without number reductions if management is adjusted to secure more uniform utilization. This may involve salting, fencing, herding, trail building, water developing, or changing the kind of livestock.

Factors Influencing Livestock Distribution. The use of salt in obtaining uniform utilization and proper seasonal distribution is very important. On mountain range, a study must be made of the proper time to graze different parts of the range. If salt is placed in all parts of an unfenced range in the spring, cattle will move quickly over the entire area, reaching the higher ranges before they should be grazed. Much can be accomplished in the way of preventing this if salt is placed only on the lower ranges in the early season.

If proper consideration is given to the forage when salt is placed on the range, localized overgrazing may be minimized. If a range supplies enough forage for 100 head of cattle for 2 months in the early season, by placing only enough salt there for 200 animal-months, the salt will be exhausted when the forage is. Too much salt will tend to hold stock in the vicinity after forage is fully used.

Since livestock are as dependent upon water as upon feed, lack of water may prevent proper utilization of forage. Cattle, and especially sheep,

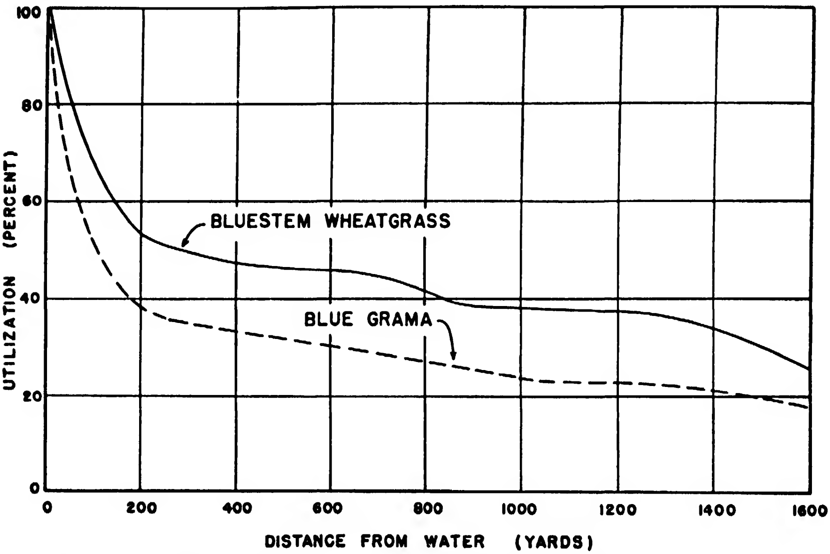

FIG. 113. Relationship between percentage utilization of major forage species and distance from water on winter range in eastern Montana plains. [*After Holscher and Woolfolk* (13)].

occasionally travel long distances with no water and regularly use snow as a source of water. However, poor water distribution is probably the chief cause of poor distribution of livestock on the range.

Studies on eastern Montana plains (13) showed that, in winter, forage utilization was virtually 100 per cent around water but declined gradually as distance from water increased (Fig. 113).

Studies on hauling water to sheep on salt-desert winter range (17) show this to be an entirely practical method of obtaining improved distribution and increased gains as well. Sheep which had hauled-water supplied gained several pounds more than those trailing to water, and their range was more uniformly grazed. (See also Chap. 16, page 404.)

Cattle customarily are not herded on the range, but many growers have found that, on rough or poorly watered range, a rider used for guiding cattle movements pays dividends. Calf crops are increased by

keeping bulls and cows distributed in proper ratio. Ranges are better utilized by pushing cattle from bottomland and onto underused steeper ranges.

Sheep customarily are herded, because the herder protects animals from predators and saves cost of expensive fencing. Unherded sheep are somewhat better than cattle in distributing themselves over mountainous range, but they, too, tend to trample out parts of the range by repeated use. Unherded sheep, for example, tend to bed on the same ridge or

FIG. 114. Sheep on trail from winter range to lambing range showing slow, open method of herding. (*U.S. Forest Service Photograph.*)

fence corner daily and may ruin large areas of range by traveling to and from these bed grounds.

Fencing to guide animal movements or subdividing the range and grazing by a rotation system are other means of improving uniformity of range use.

Sheepherding Methods. Open herding of sheep, as opposed to close herding, is an effective means of conserving the range (Fig. 114). Close herding keeps the animals bunched, and much forage is trampled into the ground. Better results are obtained by herding from in front rather than from behind, i.e., by guiding the movement of the lead animals and by avoiding the excessive use of dogs. This allows the sheep to feed quietly and move only enough to secure feed. Herding should be so planned as to

have sheep reach water not more than once a day, and they should not be allowed to shade up or to remain more than 1 hour. They should be grazed quietly toward water and never driven hastily.

By following a 1-night bedding system, excess travel is eliminated. At night, the band is bedded down on a convenient knoll or other suitable place wherever the animals finish grazing for the day. In the morning, ample forage is near, and the animals can begin grazing as soon as they leave camp; thus the period of trailing is eliminated which would be

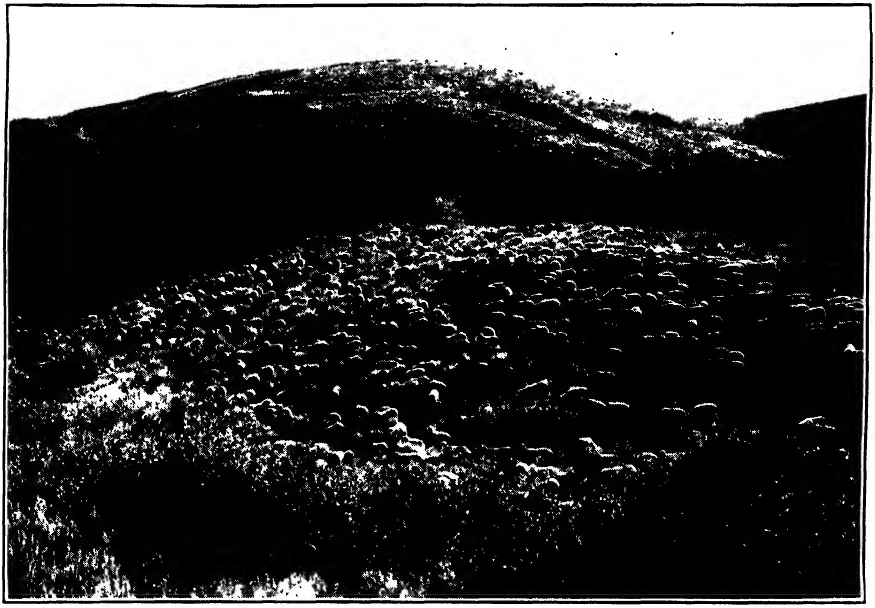

FIG. 115. Ample forage near the bed ground enables sheep to begin grazing immediately and saves trailing to forage. Such trailing is ruinous to the range and also is harmful to the animals.

necessary if they were brought into a central camp (Fig. 115). Continued bedding in the same area causes vegetation to be trampled out, and the forage in the vicinity of the camp is utilized closely until it is necessary for the sheep to move out a great distance before good grazing is secured. Again at night, after grazing has terminated, it is necessary for the herd to retravel the distance to the bedding ground, trailing over parts of the range where feed is not obtainable. The Forest Service recognizes the harm of such practices by requiring sheep and goats to be bedded not more than 3 successive nights in one place, except during lambing or kidding. Trailing sheep and cattle is harmful to range, because large numbers trample over small areas of ground within a short time, consuming often everything within reach. It is not uncommon that the

owner finds it necessary to feed sheep or cattle along the trail. Despite this, livestock trailing, especially of sheep to and from seasonal ranges, remains a common practice in the West (Table 58).

TABLE 58. NUMBER OF RANGE LIVESTOCK OPERATORS TRAILING SHEEP VARIOUS DISTANCES IN THE INTERMOUNTAIN REGION, 1938–1939*

Number of sheep per operator	Operators trailing 1-way distances of						Total operators	Average trailing distance per operator, miles
	1–50 miles	51–100 miles	101–150 miles	151–200 miles	201–250 miles	Over 250 miles		
1– 275	976	74	28	5	6	0	1,089	24
276– 750	492	71	43	29	7	0	642	49
751–1,250	390	117	42	24	6	0	579	60
1,251–1,750	159	78	36	18	3	0	294	72
1,751–2,250	129	77	41	27	4	2	280	85
2,251–2,750	65	55	36	25	12	3	196	106
2,751–3,750	69	56	40	18	13	5	201	105
3,751–4,750	33	36	29	19	10	5	132	121
4,751–6,750	34	39	36	17	9	2	137	117
6,751 or more	17	31	44	22	17	7	138	144
Total operators	2,364	634	375	204	87	24	3,688	63†

* Data from H. R. Hochmuth *et al.* Sheep migration in the intermountain region. *U.S. Dept. Agr. Circ.* 624. 1942. Includes only those operators obtaining grazing-district or both grazing-district and national-forest use. National-forest operators who do not obtain grazing-district use are not included.

† The average one-way trailing distance per sheep is 93 miles, when the averages are weighted by number of sheep rather than by number of operators.

Frequently, trailing seems the only possible method of moving animals, but it is unsatisfactory from many standpoints. Many driveways are subjected to severe utilization and the attendant results of decreased forage, increased poison-plant losses, and excessive runoff and erosion. Since many trails now follow along highways, the herds are endangered by vehicles, and they become a source of annoyance to travelers. In addition, the scenic beauty of the highway is ruined by excess grazing.

Railroads have diminished greatly the trailing of stock, but they have by no means eliminated it. With the extension of highways and forest roads and trails, truck transportation to areas once inaccessible is now possible. This is reflected in a steady increase in the number of animals hauled as compared with the number trailed; undoubtedly, the increase will continue. Experiments in Utah comparing trucking with trailing of ewes and lambs from winter range to summer range, a distance of

65 miles, showed ewes to lose 2.95 lb. and lambs 1.8 lb. during 6 days on trail, whereas trucked animals in 6 days showed a loss of 1.95 lb. for ewes and a gain of 0.5 lb. for lambs. Eighteen days later, trailed lambs had gained 6.0 lb. and trucked lambs 9.5 lb. After 36 days, lambs were marketed, at which time the gains were 13.3 compared with 16.6 lb. (39).

Studies in New Mexico (2) showed that cattle suffered 15 per cent shrinkage when driven 75 to 100 miles to market. When trucked, the loss was only 5 per cent. Cost studies, considering trucking cost and selling price, showed a $2.60 profit per head favoring trucking.

PLANNED GRAZING

Ordinarily livestock are placed on the range and allowed to remain indefinitely in the case of yearlong grazing and throughout the season in the case of seasonal grazing. This is known as *continuous grazing*, and animals have free access to any part of the range. Range use follows the same plan each year. Contrasted to this are the specialized systems of deferred and rotation grazing.

Deferred Grazing. Deferred grazing means delayed grazing. The longer the beginning of grazing on a range unit can be delayed, the better opportunity exists for new plants to become established and for old plants to gain vigor. Deferred grazing implies delaying grazing until after the most important forage plants have set seed, although with plants that reproduce vegetatively, seed maturity may have little significance.

Deferred grazing has certain distinct advantages. If grazing can be deferred every few years, then the forage plants have better opportunity to reproduce. Grazing after seed maturity injures plants less and is believed to be beneficial, since animals scatter and trample the seed into position for growth. By allowing important forage plants to grow unhindered during the period most favorable for their growth, they are enabled to produce a greater quantity of seed. Nearly equal advantages result from deferring grazing on plants that reproduce vegetatively. Rhizome production is decreased greatly with continued heavy grazing; in fact, there may be a total absence of production. Deferring grazing is not always desirable and certainly can be overdone. It must be remembered that matured forage is less palatable forage and also is poorer forage nutritionally. Also, many plants constitute increased fire hazard when allowed to remain ungrazed.

Rotation Grazing. *Rotation grazing*, or alternate grazing, involves subdividing the range into units and grazing one range unit, then another, etc., and back to the first. Subunits are fenced on cattle range and usually unfenced on sheep range. The rotation system of grazing is

based upon the assumptions that animals in large numbers make a more uniform use of the forage and that a rest from grazing is beneficial to the plant, even though it must support a greater number of animals during the shorter time in which it is grazed. The validity of the latter assumption is not adequately proved, but there can be no question that proper rotation grazing results in more uniform utilization. Larger numbers of animals in smaller units are forced to spread over the entire area and to use more or less all of the available forage uniformly. Trampling is reduced because animals are held on small areas where feed is more abundant and, hence, where less travel is necessary. Another advantage lies in a reduction of forage loss from dung. Pasture studies in New Zealand indicate that, where sheep are allowed to spend only 1 day and night in each range unit and do not return for 1 to 2 weeks, the dung is evenly spread and has dried to the extent that it is no longer objectionable to grazing animals (30). This latter point is of especial importance on small and intensively used pastures, such as under the *hurdle* system in which animals are held upon small units by means of movable panels.

An example of rotation grazing is the *Hohenheim* system developed for dairy cows in Germany, in which the highest-producing stock is placed first on each unit and followed by successively less productive animals.

Rotation should be on a sufficiently short time plan that vegetation does not become excessively mature between grazings. Many grasses, such as *Andropogon*, *Distichlis*, and *Hilaria mutica*, become tough and unpalatable if allowed to grow too rank between grazings.

Actually little is known about rotation grazing on dry range lands, though it has been used for many years for pastures and is generally recommended. A quaint dissenting opinion was voiced by Sir John Sinclair in "The Code of Agriculture" printed in 1817:

> It is indeed an important maxim in the management of grazing land, not to adopt the plan of . . . feeding alternately. . . . Fields, in the end, will be ruined by it. To maintain a proper quantity of stock, the land must be accustomed to keep it; the more it has kept, the more it will keep; . . . for each [pasture] will grow as they have been accustomed to grow, and will not readily alter their habits.

The ideas of deferred grazing and rotation grazing frequently are combined. Under such a plan, grazing on one part of the range may be deferred in spring for one or more years, then by rotation, other areas are successively given benefit of deferment until the original area again comes in line.

A change in rotational order not sooner than after each 2 years generally is considered preferable; for the seeds that are allowed to mature the first year will germinate the second year, and the young plants are given protection from grazing while they are becoming established.

Longer periods may be advisable if growth conditions are poor or if the range is in poor condition.

In its simplest form, the deferred-rotation system consists in dividing a given range into two subunits *A* and *B*. Animals are placed on unit *A* for the first half of the season to allow seed to mature on unit *B*. Unit *B* is grazed only during the last half of the grazing season. During the third year, unit *B* is grazed during the first half of the season and unit *A* is allowed to mature seed. Again, after 2 years, the original order is followed.

Rotation grazing on small pastures may be accomplished by two electric fences or temporary net fences stretched across the narrow direction of the pasture. Cows may graze between the two cross fences until pasturage is short, then one fence is moved to the opposite side of the other, cutting off a similar-sized unit. The fences are thus moved progressively forward, perhaps daily but more usually each 7 to 10 days, until the entire pasture is covered and cows return to the original unit. The process is then repeated.

Advantages of Special Grazing Systems. There is some doubt that the difficulty involved in following special systems of grazing is justified on open range land.

Early in the history of the Forest Service, the deferred-rotation system was advanced as a means of harvesting the forage and still securing proper regeneration. In comparing similar areas, some grazed yearlong, others ungrazed, and still others grazed by the deferred-rotation system, it was found that more seedlings were established under planned grazing than on unused ranges (33). This was explained on the basis that grazing following the casting of seed served to plant the seed.

Studies in Colorado (12) showed that a 9-year accumulated effect of deferred-rotation grazing as against continuous grazing at the same intensity on mixed-grass range was a 53 per cent increase in the number of stalks of vegetation. This increase was largely in good forage plants, the total number of undesirable plants actually having decreased 18 per cent. Conversely, investigations in South Dakota showed that over a 4-year period rotation grazing compared to continuous yearlong grazing gave no advantage in steer gains or in range condition (6).

Studies at the Northern Great Plains Field Station in North Dakota (34) compared continuous grazing with a three-pasture rotation system in which each was grazed but once, either spring, summer, or fall. Yearling steers failed to gain as well under rotation grazing as in continuously grazed pastures. It was concluded after 25 years of research that little benefit can be expected from rotation except in emergency attempts to improve deteriorated range or where range forage is deficient (31).

An 11-year record in southeastern Oregon (19) involved summer

grazing of beef cows under a three-pasture rotation, the May 1–October 1 season being divided into three equal parts. Continuous grazing again was found best for both cattle and vegetation. Range utilization was, however, more uniform under rotation grazing.

Eight years of data from the southern Great Plains (26) showed no benefit in steer gains from rotation grazing, and range improvement was so slight as not to justify the cost and labor of rotation grazing. Steers were rotated, generally at monthly intervals, among three pastures for about 6 summer months.

Two rotation systems were compared to continuous grazing on switchcane ranges in North Carolina (5). One involved grazing half the season in one pasture and half in a second. Another involved a 28-day rotation between two pastures. Again no advantages were found to either cattle or range.

Studies on short-grass ranges of Alberta involved a 7-month summer grazing season (15). Three ranges were rotationally grazed, each supporting cows and calves for one-third of the season. Heavily grazed pastures held up better when rotated, but gains were not increased. Under moderate grazing, rotated pastures were better maintained, but calf weights were significantly lower. It was concluded that conservative continuous grazing was most practical.

Although most range experiments fail to show advantages to rotation grazing, many pasture experiments and humid-climate experiments have shown distinct advantages.

Likely one of the major values of rotation grazing over continuous grazing on the range is better livestock distribution. Animals tend to overgraze spots of a range, grazing and regrazing the same area, while other spots may be untouched. This results because tender, young regrowth is more attractive than stemmy, coarse, older material. Rotation involves putting a large population on a small portion of the range; hence complete use is required over a short period of time. Thereby animals can be forced to clean up all parts and all species consistent with good range use.

Rotation of season of use on ranges unquestionably has advantages. Plants vary greatly in their season of palatability. If they are grazed each year at the season when at peak palatability, damage is inevitable but, under seasonal rotation, animals at some time will concentrate upon other species more preferred during another season. For example, balsamroot is palatable and susceptible to grazing damage by sheep in spring. Continuous spring grazing can eliminate it. But, by alternating spring and fall grazing it can be maintained.

A modification of rotation grazing involves a rotation of kind of stock rather than time of use. Where an operator grazes both sheep and cattle,

one area may be grazed by cattle for a few years and then by sheep for a few years. Since the kind of vegetation grazed by the different kinds of stock varies, this method allows plants highly preferred by cattle some rest, while the area is grazed by sheep, and vice versa. Continuous grazing by sheep may change a mountain range into a pure grass type, excellent for cattle but poor for sheep.

Difficulties of Special Grazing Systems. Many objections to deferred-rotation grazing are raised by ranchers, especially those doing business on big open range lands.

When a rancher is engaged in livestock production on dry range, thousands of acres of land are involved. For rotation grazing, cross fencing is almost a necessity in the case of cattle but is often prohibitively expensive. The cost may be diminished by the use of drift fences, natural barriers, and movable electric fences. Salt, too, may be used to obtain a control of stock movements. Herding may be used in certain instances. The latter methods are generally less effective than complete fencing, but they are also less expensive. As is frequently the case in the practical application of grazing principles, a compromise must be made, sacrificing some effectiveness of the grazing plan to secure decreased costs.

The cost of fences is not a major problem in deferred-rotation grazing of sheep, for they usually are under the control of a herder and may be guided to a certain unit at a certain time. Herds can be taken to the summer range via one route and returned via another, half the range being used in the spring and the remainder, which has matured seed, in the fall.

In many range areas, water is not evenly distributed, hence subdividing is difficult. Further, the water must be a season-long source; for during the rotation a given unit might be called upon to support stock at any season. If a considerable portion of a range is supplied with water only in the early season of the year, it cannot be included in a deferred-rotation system to be grazed after seed maturity.

Deferred-rotation grazing originally was designed to apply to ranges where plants cure well on the ground. In parts of the prairie region, it has been found that the grasses become too coarse to be effectively utilized toward the end of the season and, if not grazed early, there is a loss of forage.

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CHAPTER 14

ERADICATING UNDESIRABLE RANGE PLANTS

Lightning fires throughout the ages have burned forests and grasslands. Man, present in the New World for at least 15,000 years, has burned for numerous purposes connected with land clearing, hunting, and warfare, undoubtedly discouraging woody species of the native flora and encouraging grasses (32).

Since civilized man has occupied the West, and especially since 1900, two new forces have modified the ecology of range lands. These are (*a*) an increased effort to control both natural fires and man-made fires and (*b*) the fact that heavy grazing has decreased grasses which normally carry fire from bush to bush so that now many ranges will not readily burn. Decrease in burning frequency encouraged brush to reoccupy areas in which soil and climate permit its growth, many of which areas had not been so occupied within the memory of man. Doubtless decreased competition from grasses accompanying overgrazing has encouraged woody plants also in areas where they never grew before and where nature did not intend them to grow.

It has been estimated that fully a third of the present natural vegetation on the earth has resulted from fire (33). Instead of accepting these fire climaxes as natural and inevitable, man often can decide which stage is most useful to him and adjust environment to produce the desired vegetation. Use or disuse of fire as a major ecological factor in land management will have profound influence on future range production and watershed maintenance.

To an extent, both mechanical and chemical means to destroy brush have been employed as an alternate to burning and careful grazing, usually at great cost. The rapid development of selective, growth-regulating sprays gives new hope for a solution to the brush problem, but, with outstanding exceptions, present-day sprays seem insufficiently toxic to the most aggressive, and hence most undesirable, woody plants and excessively toxic to many desirable plants. Undoubtedly as sprays are made more and more specific to individual plant species or types and more readily translocated to perennial roots, and as application methods are improved, spraying will become an increasingly valuable tool in improving range land.

There can be no question that some artificial brush-control work is necessary on many range lands. Once established, vigorous woody plants such as mesquite, juniper, chamise, and sagebrush usually cannot be eliminated by good grazing practices alone, at least within economically feasible time.

Unless attention is given to land management following eradication, brush control is likely to be a continuous operation. Invasion of undesirable plants may result from natural plant succession, introduction of a new species, or change in habitat. The latter is far the most likely cause, grazing and fire being the major factors. Brush will remain until such time as the original habitat is reinstated and, often, until existing brush is removed artificially. For example, study plots in southern Arizona showed mesquite numbers to more than double over a 17-year period regardless of protection (10). On plots open to full grazing by cattle and rodents, numbers increased 108 per cent. Where both were excluded, the increase was 129 per cent. Serious reductions in perennial grass accompanied these mesquite increases regardless of grazing treatment. It was concluded that, once seed trees are present, mesquite cannot be controlled by grazing management and that, under 13- to 14-inch precipitation, it tends practically to eliminate grass and to encourage an increase in cactus.

Such studies emphasize that in some areas artificial brush control is an absolute necessity and it preferably should be done before brush density makes eradication uneconomical and while there is yet sufficient grass to grow without expensive seeding operations as well.

The expense of eliminating xeric shrubs is justified only when natural grasses are present or artificial seeding is possible; and where production following brush elimination will justify the costs. For example, in southern Arizona, elimination of mesquite resulted in doubling the yield of natural grasses within 3 years (26) and, in Idaho, sagebrush elimination (27) increased grazing capacity by 83 per cent (Fig. 118).

In general, methods of controlling undesirable plants can be classified as follows: (*a*) fire, (*b*) mechanical, (*c*) chemical, including poison or contact sprays and growth regulators or hormone sprays, and (*d*) biological. The latter includes encouragement of plant diseases, encouragement of animals which consume the undesired plant, and encouragement of plants which compete with the undesired plant. Insects and, in the case of brush, goats have been used with a measure of success to eliminate certain species. Competition is controlled largely through good grazing practices. Although once an area is occupied by a vigorous invader, elimination by grazing control is slow and sometimes impossible, still in instances it is the only feasible control (Fig. 127, page 359). It is important to know the ecology of the range, because if the presumed

invader is in reality a climax plant returning to the area after some disturbance such as fire has eliminated it, then grazing practice may not stop the reinvasion. But to prevent invasion of nonclimax undesirables on the range, no artificial treatment can compare in effectiveness or economy with good range management. A dense grass sod delays and aids in preventing establishment of most brush seedlings.

BURNING RANGE LAND

Since land was first occupied for grazing and crop production, fire has been used to subjugate undesirable vegetation, especially woody species. Because of the destructive nature of uncontrolled fire in forests and areas of settlement, fire control has become an important part of forest management. Since many range technicians are foresters by training, there has always prevailed a sentiment against burning which has persisted despite the different characteristics of the vegetation on ranges and widely different objectives in managing range lands.

Though fire is harmful in some degree to almost all perennial vegetation, the severe effect it has upon woody species does not occur in herbaceous perennials because the perennial parts are below ground. Fire is a terribly destructive force in forests and is harmful to many brush and grass ranges, but there is much evidence that controlled burning may be beneficial to many range lands.

Experimental work and years of experience in South Africa (28, 34) and in Brazil (35) indicate that fire properly controlled may be useful in management of grasslands. Season, frequency, and severity of the burning may make great differences in the results secured. For these reasons, until more information is obtained, fire should be used with caution. Provision always should be made for revegetation by either natural plants or artificially seeded plants.

Accidental range fires which occur in the wrong place and at the wrong time and which are not followed by intelligent management may do great harm. This is represented not alone by the removal of the current forage which otherwise might be used by livestock, but by the injury to perennial forage plants and soil which often is such as to decrease forage production for several years. Both wind and water erosion on lands whose protective cover has been destroyed may cause injury of a semi-permanent nature. Although burning on steep slopes always is accompanied by danger from erosion, research on this point is conflicting. Factors vary so widely that no single rule can be applied (1).

Effect of Fire upon Soil. Fire hastens the process of nitrification and large amounts of mineral material are released to the soil. This may bring about rapid increase in plant-growth rate. Conversely, where great

quantities of organic material are consumed, resulting in deposition of a large amount of ash, as in burning of forest or dense brush stands, the resultant high basicity may hinder subsequent plant growth. This evidently is a temporary condition and does not warrant the conclusion that the soil has suffered permanent injury.

Thorough investigations of the effect of burning have been made in the longleaf pine region of the South. It has long been the custom in that region to burn over the woods annually to improve pasturage. Such burnings appear actually to improve soil conditions (Table 59). In the Northwest, at shallow depths, less organic matter was found on burned forests, although at depths below 6 inches more organic matter was found (18). In Kansas, no decrease in soil organic matter and nitrogen was found to accompany grassland burning (2), the quantities depending more upon root development than upon surface accumulation.

TABLE 59. NITROGEN AND ORGANIC MATTER IN THE UPPER 6 INCHES OF SOILS FROM PINE FORESTS BURNED ANNUALLY FOR 8 YEARS COMPARED WITH UNBURNED FORESTS

Data from Greene (11)

Treatment	Organic matter, per cent	Nitrogen, per cent
Burned	1.32	0.075
Unburned	2.63	0.048

The harmful effects of fire have been attributed to high temperatures which kill soil organisms and ignite organic material within the soil. Investigation of the temperatures produced in the soil by fire shows it to be much less severe than supposed. In burning forests, temperatures above 500°F. are of brief duration, and frequently temperatures within the litter are not sufficiently high to ignite organic material (13, 14, 19). Soil moisture, wind velocity, and volume of inflammable material are factors influencing damage of fire to plant roots and soil organic matter.

Burning Grasslands. On grass ranges, fire is used to remove the unutilized herbaceous material of the previous year in order that new growth may develop unhindered by the accumulations of dead material and be readily available to grazing animals. Removing dead grass by fire results in more uniform utilization of the forage. This is especially important where growth is rank and coarse (Fig. 48, page 135).

On Kansas prairies (12), mean soil temperatures throughout the grazing season were higher on burned areas because of greater exposure to the sun and hence increased heat absorption. At a depth of 1 inch, the

maximum temperature was raised as much as 12.1°F. and at a 3-inch depth, by 3.6°F. This resulted in more rapid growth in the early spring.

Burning grasslands generally has been found to decrease slightly the yield, but this is not always the case. Infrequent burnings and, generally, spring burnings are least harmful to yield.

Quality of forage may be increased or decreased by burning since certain species are favored over others. Season of burning appears to influence plant succession. For example, in Kansas (2) late-fall-burned plots contained the greatest number of forbs and late-spring-burned plots the least. Plots burned late in the fall had successional changes toward *Andropogon scoparius*, and plots burned in late spring increased in coarser grasses, mostly *Andropogon gerardi*. *Poa pratensis* increased on unburned plots and was virtually eliminated on burned plots.

Repeated burning of bunchgrass ranges of the intermountain and West Coast areas will reduce and may ultimately eliminate these perennials, especially when followed by uncontrolled grazing. Annual grasses usually replace the bunchgrass as has occurred on the downy bromegrass (*Bromus tectorum*) ranges of the intermountain area. Such fire-overgrazing subclimaxes are usually inferior grazing lands to the original bunchgrass. Conversely, occasional burns on bunchgrass range followed by control of grazing will keep out woody invaders such as sagebrush and maintain these grasslands as excellent pasturage.

Though much remains to be learned about burning grasslands to remove accumulated plant material, clearly there is, at least in some areas, no harmful reduction in forage yield from occasional burning, provided that care is exercised as to soil-moisture conditions, wind velocity, and other influencing factors.

Since livestock prefer burned range, it is essential to burn the entire range or to burn large areas and to base stocking capacity on the burned acreage; otherwise severe overgrazing will occur on the burned area and better plants will be killed (6).

Burning Pine Forests. Burning in the southern pine region of eastern United States is a problem similar to that of burning grasslands because the fires are directed to undergrowth and ordinarily do not burn the trees. Although too frequent burning is harmful to both the forest and the soil (36), use of controlled and regulated fire in the Southeast has reached a high degree of perfection as a tool for land management (6). Probably 90 per cent of the longleaf pine forest burns at least once every 3 to 4 years (Fig. 38, page 88). Soils are slightly benefited chemically, but physical properties generally are slightly harmed and pine saplings are slightly decreased in growth rate (36). Grazing is improved by burning accumulated litter which tends to smother herbs

and grasses and by removing old grass herbage to secure more uniform grazing. Grass quality is improved the spring following a burn, and animal gains increase markedly. Even annual burning appears to benefit grazing animals. Cattle were found to gain 37 per cent more on annually burned longleaf pine forest than on unburned (36). Although annual burning is generally not recommended, some burning is essential to proper land management since unburned land trends toward a pine-hardwood-brush association which is undesirable to foresters, range managers, and wildlife managers alike (6). Fire aids in holding out the encroaching broadleaf trees and brush.

Another benefit from burning longleaf pine forests is control of the brown spot needle blight. Burning in winter at 3-year intervals controls this fungus which otherwise prevents normal pine-seedling establishment.

Burning to Eradicate Brush. Although palatable browse species are of tremendous importance as both game and livestock feed, especially on mountain ranges and intermountain salt-desert ranges, certain unpalatable shrubs, notably mesquite in the Southwest, are increasing so rapidly as to constitute the foremost range problem in many areas.

Burning to control brush is common in the chaparral zone in California, in the sagebrush lands of the intermountain region, and to a limited extent in southern prairie states, where weedy shrubs occasionally invade. Brush-burning problems are highly complex and controversial because of great variation among different areas, among different species, and among field techniques and environments. Root-sprouting plants may be increased materially by improper burning. The evergreen chaparral of California, oak brush, and mesquite are examples of shrubs which will sprout vigorously after burning. All are almost worthless for grazing and prevent full production of good forage plants.

There is evidence, however, that fire may have a place in controlling these shrubs. In the California chaparral (Fig. 26, page 70) especially, burning is commonly practiced and on deeper, more level soils, great forage increase often results, lasting usually 2 to 4 years before brush again dominates (30).

Chaparral Burning. Many chaparral shrubs are ideally suited to withstand burning in that they are able to send up root shoots, which frequently exceed in number the original stems. Because of this adaptation, the second occupation of an area may be more complete than the first if no other protective measures are adopted. A second and even a third fire may be required to kill brush sprouts and seedlings (31), although fuel shortage for follow-up burns often is a problem. The fuel shortage may be obviated by planting grass immediately following the burn so that the area may be reburned without awaiting brush regrowth sufficient to carry a fire. A rotation involving burning, seeding to grass, careful

grazing, and reburning has been recommended as a brush-removal technique (20). See also page 384.

Vigorously sprouting brush, such as chamise (*Adenostoma fasciculatum*) and manzanita (*Arctostaphylos*), begin to produce seed the third year after burning and seedlings of nonsprouting species will again produce seeds after the fifth year. Goats, deer, and even cattle and sheep will reduce seedlings and sprouts after burns (20); therefore, grazing a year after the burn generally aids brush eradication. Grazing should not be

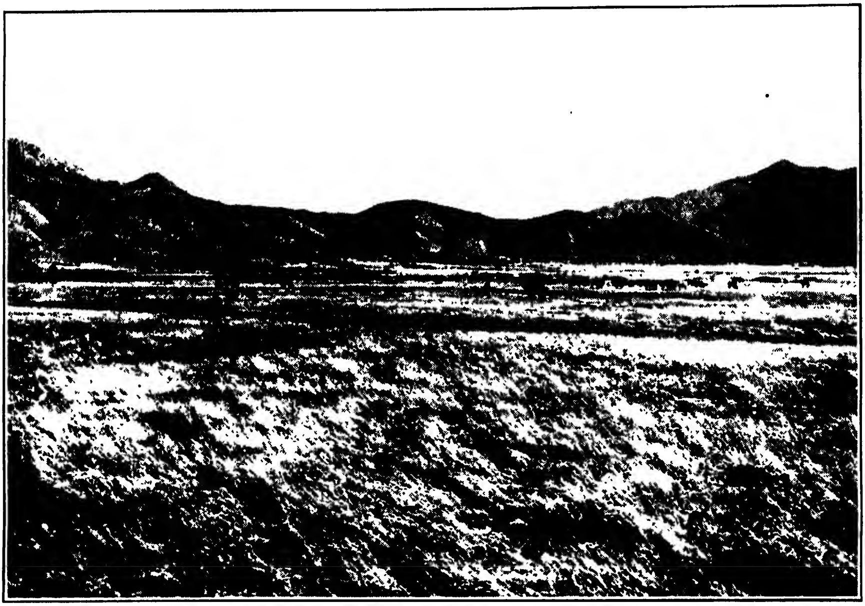

FIG. 116. Santa Rita experimental range in southern Arizona in 1903. The vegetation is mostly grama grasses, however, a group of seedling mesquites can be seen in the left center of the photograph. This range was being grazed at the rate of 40 to 50 head of cattle per section. (*Photograph Courtesy of U.S. Forest Service.*)

excessive, however, since this induces unfavorable plant succession and erosion (30).

A considerable controversy has resulted in California because stockmen are prone to burn potentially unproductive sites and may fail to control fires which are dangerous to watersheds and adjacent buildings. However, since dense brush prohibits ready movement of livestock and hunting of big-game animals and reduces forage growth, there is strong pressure toward some method of brush elimination. Brush species and associations in California are numerous and variable. Burning itself may vary greatly in intensity and nature. These variables make any over-all recommendation concerning fire impossible (1, 33), but it is widely agreed

that planned burning has a very real place in land management in the area.

Mesquite Burning. In the early part of the century, botanists theorized that fire, formerly unchecked, had maintained southwestern grasslands free of brush (5). Grazing removed fuel until misused ranges often would not burn, and civilization brought with it fire-control efforts formerly unknown. Species known to have increased as a result include mesquite (*Prosopis juliflora*), oak, juniper, burroweed (*Aplopappus tenuisectus*)

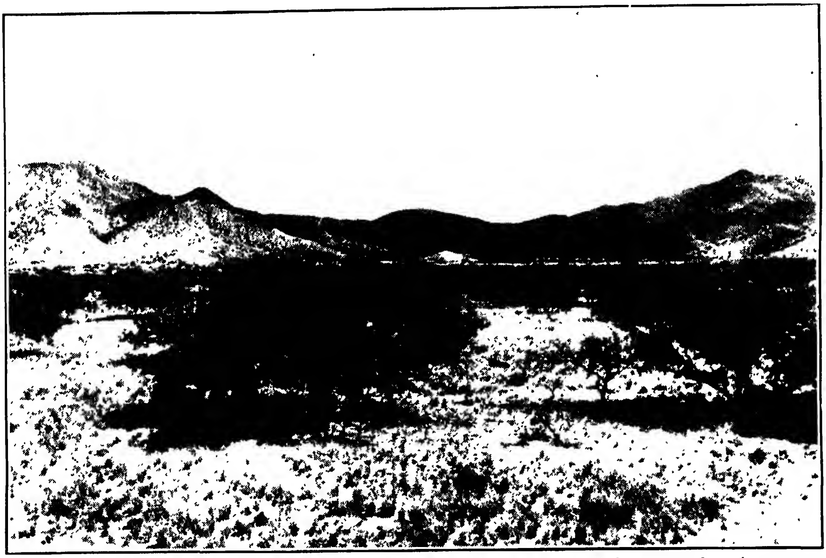

FIG. 117. The same range as shown in Fig. 116, photographed in 1941 showing great increases in mesquite and decrease in grass density. Grazing capacity was estimated at 12 to 15 head of cattle per section. (*Photograph Courtesy of U.S. Forest Service.*)

(Fig. 43, page 123), cholla cactus (*Opuntia fulgida*), and snakeweed (*Gutierrezia*). Mesquite is far the most important and widespread (Figs. 116 and 117). Three distinct varieties occur, and growth forms differ with habitat from many-stemmed bushes to large trees. Each requires somewhat different control measures.

The role of fire in the mesquite problem is uncertain. Although experimental evidence tends to link mesquite spread with overgrazing, study plots in southern Arizona (5) showed that mesquite and other desert shrubs increased even when livestock and rodent grazing was completely eliminated. It was concluded that grazing control alone was not a practical method of brush control. Nevertheless, the use of fire in control of mesquite is vigorously opposed by most ecologists because of the fire-

resistant character of the plant. Although fire often kills small seedlings and bushes, older plants and tree forms tend to sprout from the crown after fire and actually seem to increase in abundance (26). Doubtless, both fire and grazing are involved in mesquite increase.

That increases of livestock may account for mesquite increase is substantiated not only by reduced competition following overgrazing but also by the fact that cattle consume the sweet, fleshy pods of mesquite and many seeds pass through the digestive tract in viable condition at considerable distance from the parent plant. The kangaroo rat also transports and stores large numbers of seeds, however, so livestock are not essential to rapid migration of mesquite.

Studies in Arizona (16) indicate that not only mesquite but many other desert shrubs as well are reduced after fire. Despite the fact that mesquite will sprout readily when cut, many plants were killed by a single burn. The reduction persisted for at least 15 years. Late spring, the driest season of the year, appeared best for burning these deserts to obtain high shrub kills.

It is possible that in arid climates, such as Arizona's, fire is more effective in killing brush than in areas of higher precipitation. The question is by no means solved, but as yet extensive burning to control mesquite cannot be generally recommended. Deficiency of fuel in most mesquite areas is a major problem.

Burning Prairie Shrubs. In the prairie ranges, effective eradication of snowberry (*Symphoricarpos* spp.) and many weedy forbs by fire can be accomplished by late-spring burning. Economic eradication of sumac

TABLE 60. PERCENTAGE OF TOTAL STARCH AND SUGAR IN THE ROOTS OF TWO WEEDY BRUSH SPECIES IN KANSAS PASTURES
Data from Aldous (2)

Date	*Symphoricarpos*	*Rhus glabra*
Mar. 15	13.45	23.28
Apr. 10	09.02	16.86
May 12	07.36	17.87
May 23	11.75	13.69
June 7	12.27	09.45
June 21	11.29	12.92
July 2	13.56	17.25
Aug. 1	13.26	24.23

(*Rhus glabra*) by burning is impractical because the low point in food reserves comes at a period so late in the spring as to cause burning at that time to do great damage to the forage plants. Burnings at various intensities and seasons accompanied by extensive analyses of food

reserves (2) showed that burning is not effective in controlling prairie shrubs and weeds unless done in late spring, when the food reserves of the plants are low and hence regrowth after burning is reduced (Table 60.)

Burning Nonsprouting Brush. Shrubs which do not sprout from the root such as big sagebrush (*Artemisia tridentata*) sometimes can be completely eradicated by a single fire. An advantage of burning rather than plowing sagebrush is that often the good forage plants are not killed by fire and may reoccupy the area without artificial seeding (Fig. 118). Cost is usually considerably less than plowing or spraying costs, being

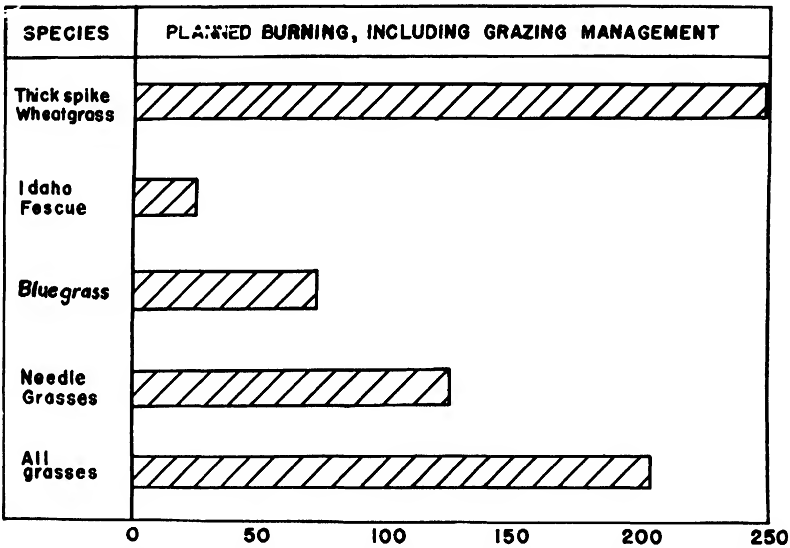

FIG. 118. Herbage production 9 years following burning on unseeded sagebrush range in southern Idaho, in per cent of production on unburned area. Grazing capacity was increased 83 per cent. [*From Pechanec and Stewart* (27).]

limited largely to the construction of good adequate fire lanes. Burning costs have been estimated at 19 cents per acre (1944 prices) for large tracts of land (27).

Sagebrush is readily killed by fire at any season. Although the brush itself burns readily because of high oil content, adequate ground fuel, usually grass, to carry the fire often is a limiting factor. Brisk wind and low humidity decrease the fuel requirement.

In the Snake River Plains of Idaho, forage production can be more than doubled by controlled burning followed by correct grazing (27). Figures 119 and 120 show results of burning in this area.

A factor determining the success of burning to increase forage on sagebrush lands is the climax status of the area. If the area is normally

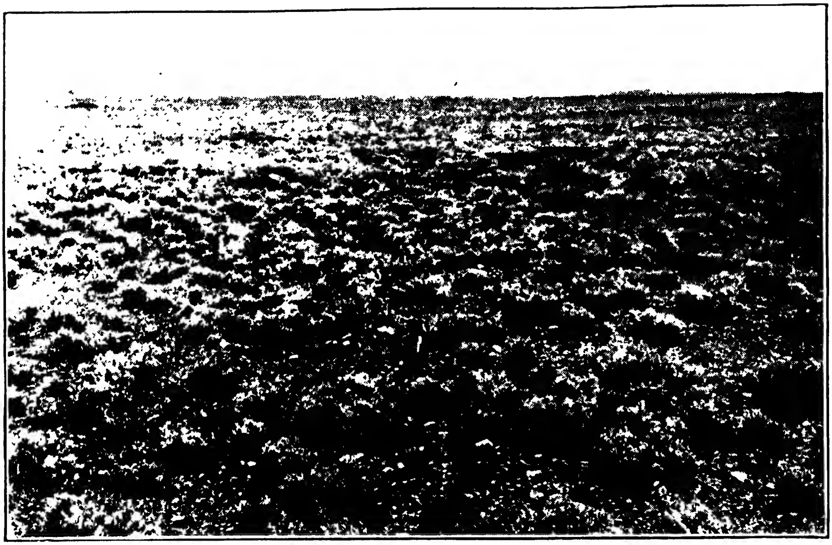

Fig. 119. An area which has been burned but which received no protection from grazing thereafter. Dense sagebrush reproduction is practically the only occupant.

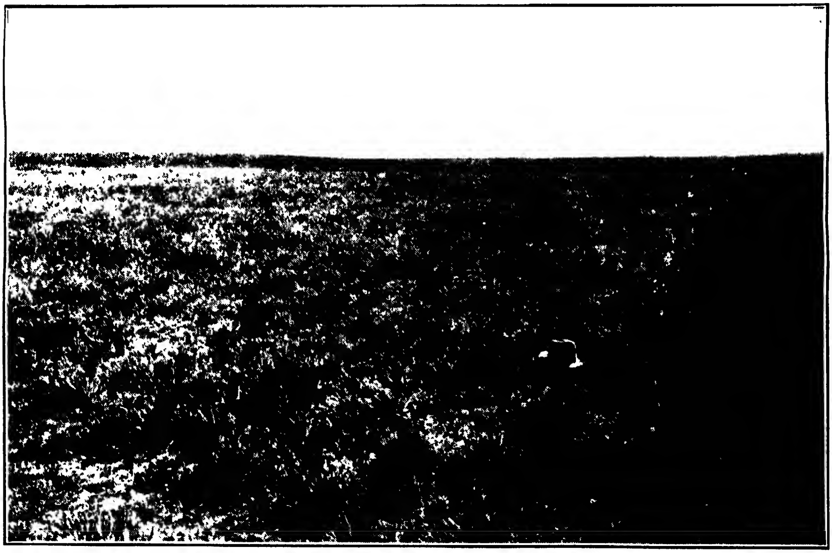

Fig. 120. An area which was burned 2 years previously and which has since been protected from grazing. Almost no sagebrush reproduction is present and grass growth has increased greatly, but there is still question as to whether grass can prevent the reestablishment of sagebrush.

dominated by sagebrush, as is much of the central intermountain area, one can never hope to keep out sagebrush permanently. If the land is climax grassland, as is much of the northern intermountain area, and sagebrush has invaded as a result of improper grazing then proper grazing after burning could be expected to keep out the sagebrush.

All ranges should be protected from grazing following a burn to allow grasses time to gain in vigor (Fig. 120), otherwise reoccupation by sagebrush may be rapid, or even worse, root-sprouting and worthless rabbitbrush (*Chrysothamnus*) may take over. Ranges where natural grasses

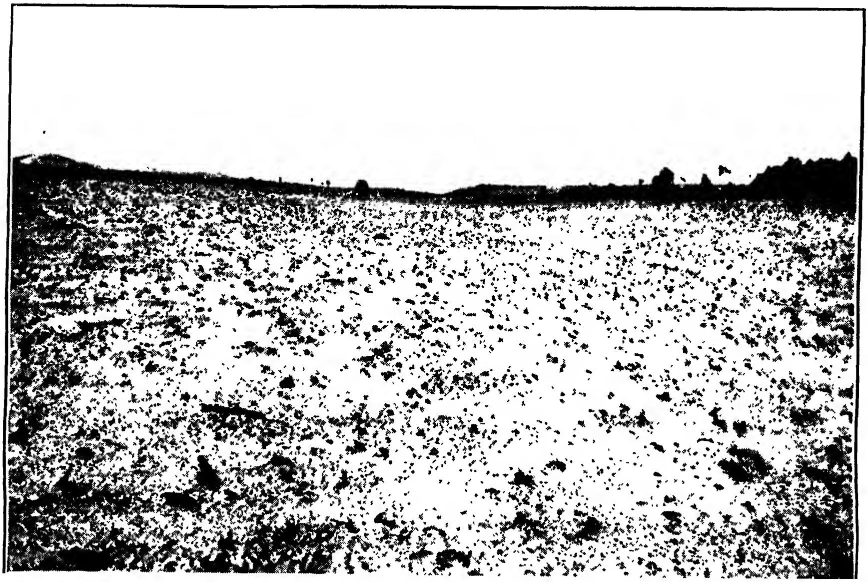

FIG. 121. Sagebrush is entirely consumed when the fire is sufficiently hot, making drilling easy. Complete consumption of brush is possible.

are almost absent, of course, will require artificial seeding following a burn. If properly burned, sagebrush land can be drilled to grass without further preparation (Fig. 121).

The worthless burroweed in Arizona can be virtually eliminated by fire, and increased grass growth thereafter appears to effect significant reduction in new seedlings beginning growth (16). It appears possible that a fire no oftener than each 10 years will keep both burroweed and cholla cactus under control.

Nonsprouting junipers such as Utah juniper (*Juniperus utahensis*) in the intermountain area and ashe juniper (*J. ashei*) in Texas burn readily and are easily killed by fire, but often fuel is insufficient to carry the fire from one tree to another.

MECHANICAL CONTROL OF BRUSH

As with burning, root-sprouting shrubs are difficult to control mechanically because of regrowth. The high cost of mechanical operations and the soil disturbance involved discourage the method except on the highly productive lands. Costs of $15 to $25 or more per acre are easily possible.

California chaparral seldom is eradicated mechanically because of cost and because the density and growth forms of the shrubs make most mechanical methods impracticable.

Mesquite and root-sprouting junipers, including redberry juniper (*Juniperus pinchotii*) and alligator juniper (*Juniperus pachyphloea*), have been controlled satisfactorily but at high cost. Repeated mechanical work or, in the case of mesquite, spraying is necessary to reduce shoots and seedlings following initial treatment.

Among the many mechanical devices used in eradicating trees and large shrubs are the following (3, 8, 25, 37):

1. *The tree dozer*, a very large tractor bearing a push bar and a V-shaped root-cutting bar.
2. *The brush cutter*, a large drum to which are affixed parallel blades. This drum can be filled with water to obtain any desirable weight.
3. *The root cutter*, a tractor bearing a 4-ft. blade on a hydraulic lift which gouges out the root crown under the ground surface. Sometimes a U-shaped blade is pulled behind the tractor 6 to 20 inches below ground.
4. *The stinger blade*, a sharp narrow digger attached to a bulldozer and equipped with a lift device to root out small trees.
5. *The brush saw*, a circular saw operated parallel to the ground.
6. *The cable drag*, a cable (or large chain), each end of which is attached to a tractor, the two tractors being driven parallel through the brush. This relatively inexpensive method is effective only on large tree with stiff trunks and is widely used for juniper control.

Large numbers of seedlings or small flexible bushes make these machines difficult to use and necessitate costly repeat operations or spraying.

Lower-growing species such as sagebrush can be controlled by a brush beater or by a whirling blade. In each, the machine depends upon rapid whirling to cut or beat apart the bushes, hence these machines are undesirable on rocky or uneven ground. A beater equipped with lengths of whirling chain suffers less breakage. Brush is pulverized to a protecting mulch on the soil surface which aids in soil conservation and protects grass seedlings. The cost of this method is high, however.

The Dixie tumbling-log harrow is successful in eradicating sagebrush from land that is rough and rocky. This is a drag composed of several logs or pipes through which have been affixed steel rods protruding 6 to 8 inches on each side. Several of these units, each tumbling independently, are dragged parallel to one another and constitute an inexpensive imple-

ment with low maintenance cost. A similar device is the *rail* drag which is composed of several variously arranged lengths of heavy railroad track.

On areas to be artificially seeded, sagebrush can be plowed by any of various heavy disk plows such as the 26-inch *wheatland plow.* These should be set at an angle of 40 to 45 degrees and should plow 2 to 3 inches deep (29). The best disk plow is the newly developed *brushland plow.* This very heavy machine was developed by the Forest Service from the Australian stump-jumper plow, and each disk moves independently on a spring enabling it to jump rocks and stumps (Fig. 122).

Fig. 122. The brushland plow being used to eliminate big sagebrush preparatory to artificial seeding. (*Photograph by U.S. Forest Service.*)

Sand sage (*Artemisia filifolia*), a root sprouter which infests large areas of the southern Great Plains, can be effectively checked by mowing, but cost is high (23). The entire top is cut off two or more times in successive years when root reserves are at their lowest point (June).

CHEMICAL CONTROL OF UNDESIRABLE PLANTS

The discovery of growth-regulator selective sprays has opened new horizons for eliminating undesirable range plants. Although still in the experimental stage, this method is widely used, with instances of remarkable success. Its chief advantages are its lesser cost compared with mechanical means, relative freedom from dangers attached to burning,

ease of application on steep and rocky ranges, and the fact that grass can escape damage.

Treating Mesquite. Early chemical eradication of mesquite was largely by kerosene or diesel oil. This is poured around the base of the plant and must penetrate enough to cover thoroughly the bud crown. Usually a quart poured around the base of a single-stemmed tree in porous soil will suffice. Bush forms and clay soils require more oil. Best penetration and kill result from treating in summer when soil is dry (9). Regrowth and new seedlings usually require retreatment (Fig. 123). Labor costs may be $10 to $20 per acre to eradicate dense brush.

FIG. 123. Mesquite in north Texas treated with kerosene at a cost of $10 per acre 6 years previously with poor results. Note sprouting and new seedlings which soon will result in reoccupation by the brush.

Various contact poisons also are effective in brush control. Sodium arsenite placed immediately on the sawed-off stump or on frilled sapwood girdling the trunk very effectively kills woody plants at any season (9). Unfortunately this chemical is highly poisonous to livestock and to man. Ammonium sulfamate (ammate) is fairly effective on mesquite and southern hardwoods when crystals are placed in cuts chipped out around the trunk or sometimes when dissolved in water and sprayed onto the foliage. These poisons will kill juniper trees, but costs generally are prohibitive.

Mesquite has proved quite resistant to growth-regulator chemicals because of its small leaf surface and its large root system which may spread over a circle of a 100-ft. diameter and penetrate 50 ft. deep. Although top kills are not difficult, it sprouts readily from the dormant

buds surrounding the trunk immediately below the ground surface if any life remains. Both 2,4-D and 2,4,5-T properly applied successfully kill mesquite, but weather conditions, vigor of growth, season of year, efficiency of application, and type of carrier all can determine success or failure.

Spray should be applied in spring while soil is moist and when plants are in active growth and full leaf. Windy days or days when rain is likely to follow should be avoided (38).

Airplane spraying of mesquite foliage is cheaper and generally more feasible than any other control method. Airplane spraying sometimes is less effective than ground spraying, but cost averages about three times as much for ground spraying. Because of rapid movement of the airplane, it is possible to cut the rate of application down to 4 to 5 gallons per acre without reducing the nozzle opening to the point that plugging becomes a problem. Amount and type of carrier may be as important as the kind of chemical to the kill. Thorough coverage is important, and generally oil carriers are superior to water.

In Texas a foliage spray of 2,4,5-T ester at ⅔ lb. of acid per acre in an emulsion of 1 gal. of diesel oil and 4 gal. of water appears satisfactory (38). Studies in Arizona (26), where climate is more xeric, are much less encouraging. Defoliation is easily attained, but permanent kill does not follow. Moist soil and rapid growth rate appear very important to mesquite kill.

Growth-regulator chemicals also can be applied effectively at any season to the bark or trunks of small trees, in frills around the trunk, or on fresh-cut stumps (38).

Spraying Other Shrubs. Control of California chamise by hormone sprays has been discouraging. However, spraying shoots with 2,4-D or 2,4,5-T in April of the year following burning has been fairly successful in controlling regrowth (20).

Sagebrush is readily killed by growth regulators, although species which do not root-sprout can be controlled cheaper by burning; and when the area is to be seeded, plowing gives a better seedbed. *Artemisia tridentata* in the intermountain area can be killed practicably by spray from airplane, when sufficient grass exists as an understory to replace the dead brush. In Wyoming, kills in excess of 75 per cent were secured with 1 lb. per acre of 2,4,5-T ester or 2 lb. of 2,4-D ester in 3 to 5 gal. of diesel-oil carrier during late spring or early summer (15). Grass increases of 200 to 300 per cent were secured by this method, but costs were high. Studies in Oregon (17) showed an equal mixture of isopropyl esters of 2,4-D and 2,4,5-T in oil emulsion to be best for killing big sagebrush, but, because of the slight benefit and high cost from 2,4,5-T, the 2,4-D alone was recommended.

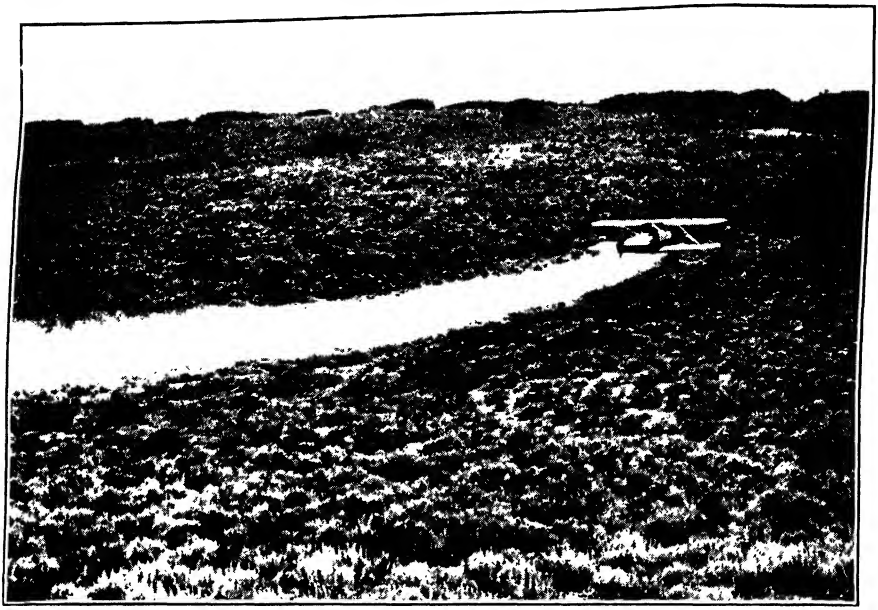

FIG. 124. Above, airplane spraying on sand sage near Woodward, Okla. Below, sage-infested range is shown on the left, and on the right is land treated by 2,4-D spraying only. Grazing returns have been doubled by this treatment. (*Photos by courtesy of E. L. McIlvain, Southern Great Plains Field Station.*)

Sand sage in the southern Great Plains can be effectively and economically killed by airplane spraying, and generally native grasses are abundant enough to result in significant forage increase following spraying. Extensive spray applications have been made since 1948 and thousands of acres are cleared of this pest (Fig. 124). Spraying 2,4-D ester at 1 lb. per acre in 3 gal. of diesel oil, preferably in May, has been found to give kills of 70 to 80 per cent (22). Plants should be in full leaf and growing rapidly (23).

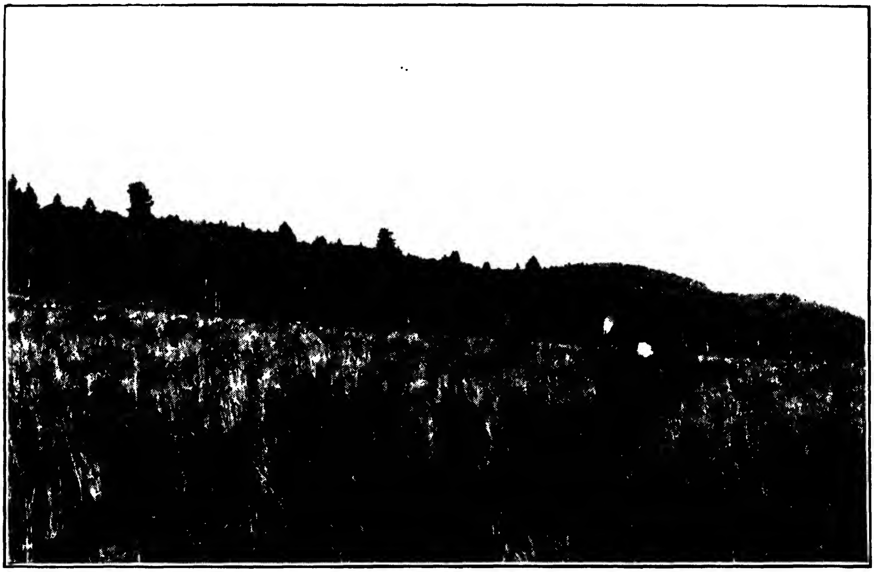

FIG. 125. Range in the foreground was densely covered by *Wyethia amplexicaulis* and *Artemisia tridentata*. A single application of 2,4-D by airplane resulted in almost complete elimination of these virtually worthless weeds and a tremendous increase of natural grasses including wheatgrass, bromegrass, and bluegrass.

Prickly pear cactus can be killed by esters of 2,4,5-T in oil carriers during the growing season (38). *Gutierrezia sarothrae* is readily killed by 2,4-D ester applied in the spring (23). Experiments with blackjack and post oak in Arkansas are encouraging, these having been controlled with 2,4-D and 2,4,5-T mix when in rapid growth. Shin oak is difficult to control, although three annual sprayings with 2,4-D ester appear to give effective control (23). No spray treatment has been satisfactory for juniper control. Rabbitbrush (*Chrysothamnus*) is highly tolerant to sprays and must be resprayed to insure complete kill.

Spraying Range Weeds. Many forbs which are poisonous or troublesome competitors can be eliminated by spraying. Mule-ear dock (*Wyethia* spp.) occurs in great abundance on certain foothill and mountain ranges of the West (Fig. 125). This almost valueless plant holds grasses in check

and reduces forage production. Spraying with 2,4-D at 2 lb. per acre during early bloom will give almost complete kill (24), and tremendous forage increase follows, usually without artificial seeding.

The poisonous sneezeweed (*Helenium hoopesii*) of the Rocky Mountain ranges can be 90 per cent eliminated by a single application of 4 lb. of 2,4-D in water during prebloom stage at a cost (1951) of $8 per acre (7).

FIG. 126. Sneezeweed (*Helenium hoopesii*), an important poisonous plant on many western ranges, can be controlled by 2,4-D spraying.

Reinvasion is rapid, however, unless followed by improved management (Fig. 126).

Other poisonous plants can be controlled if not eliminated by 2,4-D (4). Spraying with 3 lb. of 2,4-D ester killed death camas (*Zygadenus*) in early bud, and 2 lb. killed 90 per cent of the plants of lupine (*Lupinus*) and tall larkspur (*Delphinium*) after spraying two successive years. Loco (*Oxytropis* and *Astragalus*) are generally susceptible to sprays, a single application of 1 lb. per acre giving satisfactory kills on many species, and water hemlock (*Cicuta*) can be killed with 2 lb.

BIOLOGICAL CONTROL

Control of undesirable plants by introducing diseases or insects should be approached with great caution. But few instances of successful biological control from artificially introduced enemies are known. Many unfortunate experiences have resulted from the introduction of animals into new environments. The rabbit in Australia, the starling and English sparrow in America, and the muskrat in England are examples of animals whose niche in the new land was less acceptable than that in their native land. Careful and complete ecological study should precede introduction of any biological agent, to be absolutely sure that the plant or animal concerned will neither displace nor shift its activities to desirable native forms.

Notwithstanding these problems, this form of control can be extremely effective as well as economical if properly used. Insects have in several instances been employed with success to bring undesirable plants under control. In Australia the prickly pear problem has been eliminated by the introduction of moths which feed upon the plant. Lantana (*Lantana camara*) in Hawaii and gorse (*Ulex europeus*) in New Zealand have been brought under control by seed-eating insects. In America one example gives promise of being an effective means of plant control. Saint Johnswort (*Hypericum perforatum*), a native of Europe, has spread widely throughout the Far West, where it has given trouble as a stock-poisoning plant. The introduction of a beetle (*Chrysolina*), also native of Europe, which feeds exclusively on Saint Johnswort, promises to hold the plant in check. Not only do the adult beetles feed upon foliage of Saint Johnswort, but the larvae live in and feed upon the crowns and shoots of the plant.

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CHAPTER 15

ARTIFICIAL SEEDING OF RANGE LANDS

When man first began using western ranges, most of the land was vegetated by plants of quality and abundance as great as existing climate and soil permitted. Much of this natural vegetation has been destroyed by misuse or plowing. Some of the misuse came about because ranchers thought that the loss of native forage was not serious since it could be replanted.

Many technical people fear overoptimism for range seeding on the part of ranchers for several reasons. Range seeding generally has proved successful only on the more favorable sites and is in no sense a substitute for good range management. Furthermore, its costs are so close to its values that only careful adherence to approved methods can be expected to prove profitable. In many areas there is reason to question that equivalent quantity or quality of forage can be produced artificially as was present originally. If soil loss accompanies vegetation destruction, which is very likely, there is question that either expensive planting or good management can return original production within our generation. Range land, like farm land, can produce well only if soil is good and moisture favorable. No miracle grass is known which will grow in spite of poor management and unfavorable environment (45). If a range is not now producing, misuse or unfavorable growing conditions is the likely cause. There is no value in planting such areas unless this cause is found and cured.

In planning management of a range, the potential of the land should be examined in terms primarily of climate and soil. Then existent vegetation should be appraised to determine the relative merit of artificial planting compared with natural revegetation. Further, possibilities of changing management of the area should be studied to determine how the misuse which made revegetation necessary can be corrected. Then, and only then, should artificial seeding be planned. It is important that ranchers not succumb to blind enthusiasm after seeing a few spectacular successes. Careful, scientific seeding has wonderful possibilities, but it is a major undertaking which should be attempted only after proper planning.

If a reasonable stand of perennial forage is present and growing well, range land should not be disturbed for artificial seeding. Reduced rather than increased forage is possible. Artificial seeding should be used only when the range cannot be improved by good management within a feasible time (Fig. 127). Denuded ranges or abandoned farm lands cannot be expected to improve rapidly because no source of seed is available. These areas may require 25 to 50 years under favorable conditions to regain climax vegetation (6, 38), a period which is economically infeasible. Taxes over such a period might well exceed the value of the land. Under such conditions artificial revegetation is essential. Abandoned farm lands

FIG. 127. Protection from heavy grazing for several years resulted in a good stand of wheatgrass, ricegrass, and valuable bitterbrush (*Purshia*) on this range. Note stalks of dead sagebrush killed out by grass competition. No artificial seeding was done.

are the first choice for grass seeding because they are the best sites and they require a minimum of preparation. Often they can be drilled with no plowing or fallowing.

As early as 1895, the federal government began grass planting experiments in the West, but 1,500 trials brought largely failure, and the optimism over range seeding was lost. Again in 1907, the U.S. Forest Service began a large seeding program, but 500 tests in 11 states gave only about 16 per cent success, even on favorable locations.

Since 1935, research has made rapid progress. Development of new machinery and planting methods, along with promising new species of grass, has paved the path for progress. By 1948, however, U.S. Department of Agriculture experts estimated that only 5 million acres of the

80 million in the United States in need of replanting had been completed (30).

SEEDING METHODS

A great variety of seeding techniques have been developed for use on western ranges. The tillage method, the season, the grazing protection provided, and the species used are major variables. Each of these may account for success or failure despite natural factors such as weather and soil.

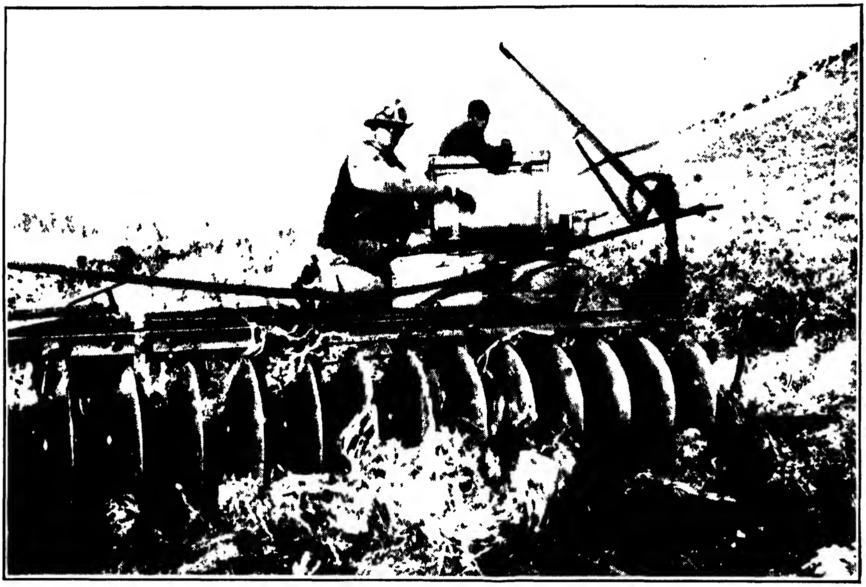

FIG. 128. Broadcasting grass behind a big wheatland plow in the early fall is an effective way to seed sagebrush lands in the intermountain area. Power-driven broadcasting devices have largely replaced hand-seeding shown here.

Broadcasting. Much of the early range seeding was undertaken without soil treatment, seed merely being broadcast indiscriminately. This lack of treatment resulted from prohibitive cost of tillage and the fact that many areas were rocky, of rough topography, and covered with brush or other native vegetation.

In general, land not suited to drilling should not be seeded, but there are many exceptions. A few grasses, notably *Poa bulbosa* and species of *Sporobolus* and *Eragrostis* appear to be unusually well suited to broadcast seeding (30). Some species such as the needlegrasses (*Stipa*) and alfilaria (*Erodium*), have twisted awns which enable them to plant themselves.

Highly successful broadcast seedings have been made immediately after rough-plowing or disking land, especially in the fall (Fig. 128).

Also, seeding under broadleaf trees immediately preceding leaf fall in autumn has proved successful since the seed is adequately covered and protected by the leaves.

Covering seed presents the least serious problem on light, fluffy soils, especially on those which have been loosened by frost action, which leaves many small cracks to receive the seed. The loose ashy surface left by a burn is physically adapted to broadcast seeding. Even on these loose and porous soils, however, broadcasting is usually more effective if the seeding is followed by a seed-covering operation. A heavy chain, harrow, or brush drag is sometimes used. Also, driving a herd of stock over the land will trample the seed into the ground.

It often proves impractical to cultivate large areas of arid range land intensively. Other less thorough methods have been developed, such as plowing strips or plowing occasional furrows along the contour and limiting the seeding to these areas. These furrows may be 4 to 15 ft. apart, and seed can be broadcast on the rough surface immediately after plowing. The concentration of water that results from furrowing ensures a good stand of grass within the furrow, and natural seeding of the plants so established is depended upon to fill intervening spaces.

Many practical and effective seed broadcasting devices are now available for hand use, for attachment to power-drives on tractors, or for use on airplanes. Broadcasting seed from an airplane is cheaper and more efficient than hand broadcasting and has given good results on mountains of western Montana and elsewhere, especially immediately following hot burns (11). Airplane seeding on unprepared dry range, however, has generally not given good results. Broadcasting of pelleted seed from airplanes, despite much publicity, is not recommended. Although seeds encased in absorbent plastic materials are easier to distribute evenly from the air, pelleting in mud under high pressure greatly reduces germination and gives no advantage.

Since broadcast seedings are less likely to succeed than drilled seedings, a greater quantity of seed should be sown.

Preparing Land for Drilling. When range land is to be drilled, more careful preparation is recommended. Even here, however, intensive tillage is avoided because of cost and also because of likelihood of excessive loosening of the soil surface and bringing up heavy, infertile subsoil (28).

The amount of cultural treatment necessary in range seeding is dependent upon climatic conditions, existing plant cover, the species being planted, and the physical condition of the planting site, particularly the soil.

Good seedbed preparation seeks to retain a firm seedbed, favor infiltration and storage of moisture, and leave a trash-covered surface. Shallow disking usually accomplishes this. On loose and deeply tilled

soils, it is almost impossible to keep the seed close enough to the soil surface. Under such conditions, some provision for packing the seedbed is desirable. Packing also gives the seed better contact with the soil and facilitates transfer of water. Natural packing may accomplish this if the plowed land is allowed to remain undisturbed a few weeks before planting.

Competition from vegetation already present frequently is responsible for seeding failures. Numerous experiments have showed conclusively that grass should never be planted into dense stands of annual grasses. Conversely, some weeds are considered desirable because the protection that they furnish the young grass from sun and wind is believed to offset the competition for soil moisture. Russian thistle (*Salsola*) grows late in the season and offers little competition in early spring when the grass begins growth. This principle gave rise to the idea of planting a *nurse crop* with grass to protect it from drying sun and eroding wind. However, such crops actually rob the grass of essential soil moisture. Studies (43) of grain nurse crops used in range seedings showed all intensities of grain seeding to decrease the establishment of perennial grasses on dry lands in Utah. In the southern Great Plains (38) and Montana (34) similar results were secured.

Since fallowing arid land to rid it of weeds is expensive and conducive to soil blowing, the *preparatory crop method* was developed. This method of seeding (23) consists of plowing land occupied by competing weeds such as cheatgrass, planting to a cereal grain which is harvested as usual, and then drilling to grass the following fall without further land treatment. The income from the grain is expected to cover costs of the operation. A four-year planting program on abandoned farm land in Montana averaged a cost of $14.59 per acre by this method and the return from grain averaged $19.14 per acre. Seventy-eight per cent of the costs were for planting the preparatory crop and 22 per cent for follow-up seeding of crested wheatgrass.

In the southern Great Plains, a close-drilled sorghum crop is planted late in June or July so that the crop will not mature seed. This is grazed in fall, helping to pay costs, and grass is drilled into the stubble the following spring. Such stubble prevents wind erosion and reduces surface crusting and drying (30).

Where nonsprouting brush such as sagebrush is present on an area to be seeded, the brush may be reduced by dragging several lengths of heavy railroad rail over the land. A heavy chain dragged between two tractors serves a similar purpose.

Burning also is an effective method of reducing brush competition, especially from nonsprouting brush. Burning has been found highly effective for sagebrush control (Fig. 129). Although costly fire lanes must be constructed to ensure safe burning, fire generally is a less expen-

sive brush control than mechanical treatment. Spraying also is used to reduce brush stands. For additional information on brush control, see pages 341 353.

Drilling. Drilling is preferred to broadcasting where the soil is sufficiently level and free enough from rock and brush. A double disk or deep furrow drill with narrow press wheels is desirable for seeding small-seeded grasses. Drills are now available with a flange around the disks about an inch from the cutting edge to prohibit excessively deep planting. Drills have been developed that have outrider wheels enabling them to be

FIG. 129. This sagebrush range was accidentally burned in late fall. One week later it was drilled to crested wheatgrass at 6 lb. per acre without any other treatment. This excellent stand resulted after one year. Unburned brush is seen in the background.

used on slopes up to 65 per cent and that are narrow enough to pass between brush (31). For light grass seed, an agitator is essential to uniform seeding. Even with the agitator, some seeds are so protected by awns and hairy coverings that they clog the drill vents. Methods of processing such seeds to remove these appendages have been developed (39).

Blocking some of the drill openings to obtain wider row spacing may be desirable on arid lands. Too wide spacing, however, enables weeds to grow between rows (Fig. 46). On ranges, a row spacing of 12 to 14 inches generally is the maximum desired, although for seed production, where inter-row tillage is possible, spacings of 30 to 42 inches are not unusual.

A common cause of failure in range seeding is too-deep planting. Drilling should generally be as shallow as possible, seldom over 1 inch. Sometimes, as with the deep-furrow drill, seed tubes are removed from the shoe or disk and seed is dropped on the top of the ground. Sloughing of soil into the furrow then covers the seed.

The quantity of seed passing through the drill can be regulated by the drill indicator; but because grass seed is smaller than grain seed, the scale must be adjusted. Table 61 shows some drill settings that have

TABLE 61. APPROXIMATE AMOUNTS OF GRASS AND LEGUME SEED, IN POUNDS, DELIVERED BY A GRAIN DRILL SET TO SOW VARIOUS AMOUNTS OF WHEAT
After Walker and Bracken (48)

Kind of seed	Drill indicator set for wheat			
	1 bushel	1/2 bushel	1 peck	0
Alfalfa and sweet clover	..	..	..	10–12
Crested wheatgrass	21	14	7	
Slender wheatgrass	14	10	6	
Western wheatgrass	9–10	6–7		

been found correct for various grasses with all drill openings functioning. The quantity of seed passing through the drill can be determined more exactly by revolving the wheels and allowing the seed to drop on a sheet. The area that would be seeded can then be calculated by multiplying the drill width by the wheel perimeter by the number of revolutions.

The amount of seed planted should be just enough to secure a stand that will fully use the available moisture. Less will allow weed invasion. More will be wasteful but also may actually reduce the vigor of the seeded grasses through excess competition among themselves. Seeding rate will vary with kind of seed from perhaps 1 lb. per acre for small seeds like the lovegrasses to perhaps 8 to 10 lb. for large seeds such as tall wheatgrass. Productivity of the site also is important. Good sites should be seeded at higher rate than poor sites which cannot support dense stands.

SEASON TO PLANT

The most important factor influencing the season for planting is distribution of precipitation. In the far-western states, only 15 to 40 per cent of the total annual precipitation falls between April and September, whereas, in the plains states, 50 to 80 per cent falls in this period (Figs. 8 and 130). In regions of heavy winter precipitation, fall seeding is favored; in regions of heavy summer precipitation, spring seeding is advisable.

Snow likewise has an important influence upon the season of planting. Generally, heavy winter snows, which protect young seedlings from extreme cold, are conducive to fall plantings. Areas where winter temperatures are low, but where the soil is bare during parts of the winter, are likely to be best adapted to spring planting. Alternate freezing and

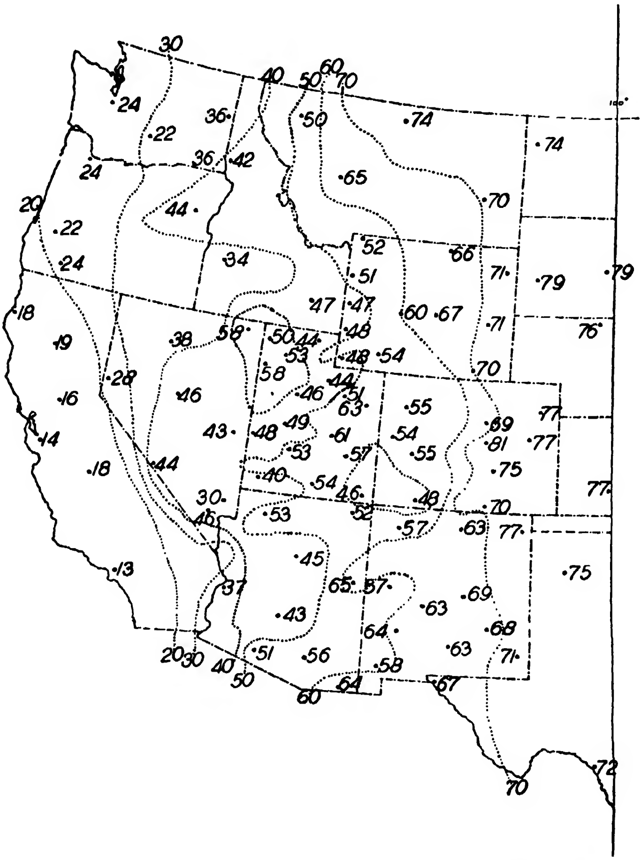

FIG. 130. Precipitation distribution in per cent of total falling during the summer months (April to September) for western United States. [*After Stoddart* (44).]

thawing of exposed soil in winter will cause fall-germinated grass seedlings to be heaved from the soil. Areas in which low temperatures are not expected can be seeded just prior to the season of greatest normal precipitation.

In areas of heavy winter precipitation, the type of soil may influence season of seeding. Sandy and well-drained soils can be worked early in the spring. Clay soils and poorly drained lands cannot be planted until

they have dried out in late spring, and therefore fall planting usually is desirable. A major objection to spring planting is that usually only a short period of time exists between a too wet and a too dry soil, and this is the time when farmers and ranchers are busy with many other spring emergency jobs.

WHAT TO PLANT

The rancher may choose from literally hundreds of native or cultivated grass species for range seeding. Unfortunately, few forb or brush species are usable. Brush species do not permit ready seed harvesting and hence are almost unused despite rather encouraging experimental results. Legumes are highly desirable because they add to soil nitrogen and improve animal nutrition. Cultivated forbs such as alfalfa and sweet clover are successful and desirable where precipitation permits their growth; however, forbs are not commonly used.

Seeding annual cereal crops on range land, especially for early-spring feed, has been recommended widely in recent years. Rye and barley are used most because they volunteer readily and do not have to be seeded each year. Though certain conditions justify the use of such species, perennials generally are preferred.

Range research has only touched upon the problems of introducing forage plants from other countries (or, indeed, of cultivating native species of America), of cross-breeding range plants, or of selecting among varieties and ecotypes within established species. The difference in performance between strains of one species is in many cases a far greater variable than the difference between species (13).

That individuals within a species are not alike in behavior is strikingly shown in studies (36) of blue grama plants grown at Hays, Kans., from seed obtained from various sources. These plants, taxonomically the same, behaved in remarkably different manner (Table 62). The author concluded that seed harvested locally produced more desirable plants than that harvested farther north, and that plants of southern origin excelled in forage production but might not withstand environmental conditions farther northward. U.S. Department of Agriculture experts (30) also recommend that locally grown seed or seed from farther south be used in range planting. Most native grass seed when planted south of its source produces plants of low vigor and productivity.

Mixtures. Mixtures of plants appear to have several advantages over pure stands. (*a*) All areas have variable conditions of soil, moisture, and slope. In mixtures, each species produces abundantly on the site more nearly supplying its needs. (*b*) Different rooting habits may result in more efficient use of soil moisture and nutrients from various soil depths. (*c*) Seasonal forage production is likely to be more uniform because

periods of lush growth and dormancy vary in different species. (*d*) A mixed diet is likely to be more desirable to the animals and produce greater gains, especially when browse plants and legumes are included. (*e*) Some plants of the mixtures may have favorable influences on others. A notable example is the nitrification accomplished by legumes, which increases vigor of grass growth and also increases its protein content.

TABLE 62. SOME MEASUREMENTS OF BLUE GRAMA GRASS PLANTS GROWN AT HAYS, KAN., FROM SEED FROM VARIOUS SOURCES
Data from Riegel (36)

Source of seed	Herbage weight per plant, end of first season, grams	Depth of roots, end of first season, centimeters	Depth of roots, end of second season, centimeters	Spread of roots, end of second season, centimeters	Number of seed spikes per plant, second season
Arizona	79.5	156	287	96	77.0
New Mexico	47.4	240	240	34	96.0
Texas	29.1	165	255	34	68.5
Kansas	26.8	78	180	80	103.5
Nebraska	24.5	130	272	38	115.0
Colorado	29.8	110	250	36	104.0
Wyoming	26.1	65	250	33	49.5
North Dakota	18.1	80	222	26	56.0
Montana	15.1	155	267	35	40.8

The use to be made of the seeding and palatability of the species may determine whether mixtures are desirable. In mixture, highly palatable species like sand lovegrass may be killed out. Low-palatability species like some wheatgrasses may be underutilized. Grasses that mature or reach maximum palatability or nutritive value at different seasons might best be planted alone so they can be managed according to individual requirements.

PROTECTION FOLLOWING SEEDING

One requisite to successful revegetation of range land is protection of the area from grazing animals. All investigators are agreed that, if seeding on dry lands is to be successful, animals must be removed and kept from the area until the seedlings have become established. Otherwise, the plants that escape the ravages of drought may succumb to grazing animals.

Sometimes several years of freedom from grazing appear desirable; but, under practical conditions, this is seldom feasible. Under no con-

dition should a seeded range be grazed during the growing season immediately following planting. If possible, it should be protected the following year as well, at least during the spring growing period. This allows the plants to become firmly rooted. Stocking should be light until the new plants are well established. Protecting newly seeded areas from heavy use by rodents and insects, of course, is as important as protecting from livestock. Jack rabbits, especially, do tremendous damage.

COST OF RANGE SEEDING

An important consideration in seeding is the cost of the project in relation to the increase in carrying capacity. Under certain circumstances, such as the seeding of a critical erosion area by government agencies, strict dollar-and-cent relationships may and indeed must be ignored; but, with private operators, seeding must pay by increasing the grazing values.

The cost of seeding will vary with kind and amount of seed, degree of preparation of the soil, and expense of protection until established. Income can be measured by increase in productivity and by permanent increase in land value.

In appraising value of production increases, grazing-capacity increase is not the only factor that should be examined since animal performance may improve as well. For example, when mountain lands in central Utah were seeded, it was possible to reduce the range allotted to each ewe from 1.47 to 0.85 acres per month, but lamb marketing weight increased from 79 to 90 lb. and lamb percentage increased (27). Other indirect benefits included decrease of erosion and flood-damage hazards, ewe-death losses were reduced, grazing season was lengthened, and farm production was increased because the season sheep were on cropland was decreased.

Wyoming studies (2) showed that grazing capacity of crested wheatgrass was 143 sheep-days per acre compared to 60 on native grass range, and the pounds of lamb produced per acre increased from 29 to 89 lb.

The extent to which range seeding benefits a ranch depends upon how well the site will respond to treatment and how long the benefits will continue under the kind of management planned (33). The answers to these questions are not known under most western conditions.

Costs are highly variable among ranchers and ranches, even for the same operations under identical economic conditions. Costs in eastern Oregon varied from $2.75 to $18.25 per acre (Table 63), depending upon physical conditions and rancher efficiency (33). In the event of partial or complete failure, at least part of these expenses would need to be repeated.

Cost of seed also varies greatly. New species and those with small seed and seed difficult to handle frequently reach prices of $1 or $2 per pound. Most standard species, however, can be purchased for 15 to 30 cents per pound.

Early studies (29) on range-seeding costs were optimistic. Assuming capacity increases as high as 1.5 animal unit months per acre and omitting fencing costs and interest charges enabled seeding for $1.81 to $4.50 per acre (1933 to 1943) to yield annual income increases of 35 to 54 cents per acre. Thus costs presumably could be returned in 7 to 8 years. In spite of the author's forecast that improved methods would soon result in reduced costs, the same operations now cost up to $10 per acre (30).

TABLE 63. EXPECTED COSTS OF VARIOUS RANGE-SEEDING OPERATIONS ON THE BASIS OF 1950 METHODS AND PRICES, EASTERN OREGON
Data from Plath (33)

Operation	Usual Cost per Acre
Clearing (sagebrush):	
Burning	$0.40-$0.50
Mechanical means	3.00- 3.50
Spraying, no removal	6.00- 7.00
Seed	1.50- 3.50
Seeding:	
Drilling	0.75- 0.90
Hand broadcasting	0.60- 0.85
Airplane broadcasting	0.75- 1.00
Fencing where needed	2.00- 5.00
Interest on investment	0.50- 0.75

An important consideration in seeding-cost analysis is the extent to which permanent land values are increased. Recent studies in Wyoming showed that seeded range correctly grazed (slightly less than 1 animal unit month per acre for crested wheatgrass) for 8 years had declined 55 per cent in production. Seedings of western wheatgrass and Russian wild rye dropped most; crested wheatgrass and alfalfa least. It would appear, however, that somewhat lighter grazing might prevent this decline.

The financial hazards involved in range seeding emphasize the importance of developing low-cost yet effective methods. Most areas can be replanted satisfactorily if cost is no item; the primary consideration in a proposed range-seeding program is financial. Costs generally are too high under present-known methods and present high labor costs except on land capable of high production. Although there are many supplemental benefits from range seeding, still many ranchers cannot afford to finance an expensive seeding operation unless it has reasonable opportunity to return at least a dollar's worth of forage for each dollar expended.

NATURAL REVEGETATION

On most range land, misuse has not progressed to the stage at which the land is devoid of good forage species. Protection from grazing, which is essential to the success of artificial seeding, often will result in surprising improvement to these ranges without resorting to artificial seeding (Fig. 127). These natural species, under protection and good management, will gain in vigor and revegetate the range without cost other than that involved in improved management. This does not necessarily mean removal of livestock or, in all cases, reduction of livestock. It has been shown that grazing after seed maturity effectively plants seed natural to the area. In many instances, if seed plants remain, an adjusted grazing program to allow the seeds to germinate and grow is more to be desired than an artificial seeding program of doubtful effectiveness.

Natural revegetation necessitates the presence of seed plants of the desired species. Thus, in the Southwest, areas having 15 per cent of the ground covered by perennial grass should not be artificially seeded (26). Though perennial species may not be obvious, close examination will often reveal their presence under protecting shrubs. These plants may require a period of 5 years to regain a vigor that will enable them to seed at a normal rate; and, depending upon weather conditions, several more years may be involved before a marked increase in numbers takes place.

Observations on many range seedings show that native plants have responded to grazing protection and frequently are more abundant on the seeded area than are the artificially planted species. Ranchers unfamiliar with species assume that the result is a product of their planting when actually it is nature's own doing.

Certain land treatments on natural range such as contour furrowing or pitting by use of an eccentric one-way disk (Fig. 131) improve moisture absorption and increase production without seeding. Wyoming studies (1), for example, showed short-grass plains to produce 9 lb. more lamb per acre each year following a single pitting operation, the cost of treatment being only 50 cents to $1 per acre.

REGIONAL CHARACTERISTICS OF RANGE SEEDING

Because of the vast differences found in the climate and soil of the West, it is necessary to consider the artificial revegetation problems of various regions separately as follows: (*a*) the northern Great Plains, (*b*) the southern Great Plains, (*c*) the Southwest, (*d*) the intermountain region, (*e*) the Pacific Coast, and (*f*) the Northwest (Fig. 132).

FIG. 131. Above, an eccentric one-way disk developed to pit range land to promote natural revegetation and increase forage. Below, land pitted by the eccentric disk. (*Photographs by O. K. Barnes.*)

The Northern Great Plains. The northern Great Plains are characterized by cold winters, uncertain moisture, and heavy winds. The precipitation generally is concentrated in the early spring and midsummer.

Because of severe climatic conditions and danger of soil blowing, it is desirable to provide protection for seedlings until they are partly established. This protection may be obtained by seeding into the stubble of a grain crop (23). On abandoned lands and eroded fields, seeding directly into the weed stand has proved preferable to intensive cultivation (50). Where downy bromegrass (*Bromus tectorum*) is present, however, competition is so severe as to make such planting almost impossible (41).

FIG. 132. Regions of western United States having similar problems in range seeding.

Although fall planting has been successful, cold winters, and soils swept bare by wind, make early spring seeding generally advisable. Blue grama is best planted in late spring (41).

Crested wheatgrass (*Agropyron cristatum*) has proved to be so well adapted to the northern plains region that it appears to be superior not only to other cultivated species but to the native species as well (Figs. 133 and 134).

Experiments near Moccasin, Mont. (51), compared the grazing capacity of crested wheatgrass, smooth bromegrass (*Bromus inermis*), and natural stands of mixed native grasses, including blue grama (*Bouteloua gracilis*), Sandberg bluegrass (*Poa secunda*), needlegrass (*Stipa comata*), and western wheatgrass (*Agropyron smithii*). Over a 7-year period during which the pastures were grazed by beef cattle, the average date of

beginning grazing was April 22, May 1, and May 18 for crested wheatgrass, smooth bromegrass, and native grasses, respectively. Duration of the grazing season was 125, 113, and 93 days, respectively. In addition to the longer grazing season, differences in the number of animals grazed resulted in an average of 33.1 animal-days of grazing per acre for crested wheatgrass compared with 21.5 for smooth bromegrass and 15.1 for native grasses. The crested wheatgrass produced 70.2 lb. of gain per acre,

FIG. 133. Crested wheatgrass (*Agropyron cristatum*) has proved to be better adapted to dry range lands, especially in the northern Great Plains, than any other introduced plant.

or 259 lb. per head; the bromegrass 45.5 lb. per acre, or 238 lb. per head; and the native grasses but 32.5 lb. per acre, or 192 lb. per head.

Other species successful on Montana plains (41) are intermediate wheatgrass (*Agropyron intermedium*), hard fescue (*Festuca ovina* var. *duriuscula*), and green needlegrass (*Stipa viridula*).

The Southern Great Plains. The southern Great Plains area is hot in summer and is characterized by high evaporation. The winter temperatures over most of the area are not severe, some southern parts being

almost frost-free. Precipitation, especially in the western parts, is low and occurs mainly in late spring or early summer. Heavy winds coupled with severe droughts are common.

Intensive cultivation and fallowing are not recommended over much of the southern Great Plains because of wind-erosion danger. Drilling grass into Sudan grass stubble has been successful. Broadcasting hay of a mature grass is recommended for many native species whose seed is

FIG. 131. A stand of crested wheatgrass in central Utah growing under approximately 10-inch rainfall.

not obtainable on the market. Hay can be broadcast on either prepared or unprepared seedbeds and pressed into the ground by use of a packer or disk, or even by driving livestock over the area (49).

Late fall and early spring are the best seasons for planting. The supply of moisture in the soil, the abundance of weeds, the grass species, and the degree of grasshopper infestation determine which season is preferred for a particular year (14). Seeding warm-season grasses in February and March is recommended in Oklahoma and Texas (25); however, fall plantings are made in south and southwestern Texas, and July and

August appear the best season in the Trans-Pecos area. Cool-season grasses are planted from September 15 to October 15.

Among the successful native species for sandy soils are sand lovegrass (*Eragrostis trichodes*), blowout grass (*Redfieldia flexuosa*), giant sandgrass (*Calamovilfa gigantia* and *C. longifolia*), sand dropseed (*Sporobolus cryptandrus*), and sand bluestem (*Andropogon hallii*). For less sandy soils, the following have been successful: blue grama (Fig. 135), plains bristlegrass (*Setaria* spp.), western wheatgrass, buffalo grass (*Buchlöe*

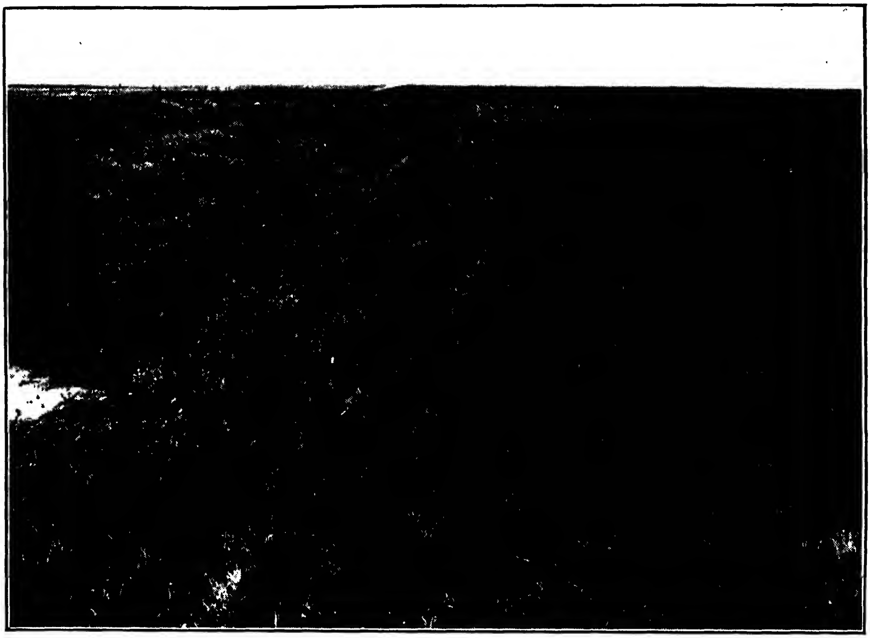

FIG. 135. Blue grama (*Bouteloua gracilis*) one year after seeding on abandoned cultivated land in western Kansas. Thousands of acres in the southern Great Plains have been revegetated in this manner. (*Photograph by F. W. Albertson.*)

dactyloides), sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), and, for the extreme southwestern parts, curly mesquitegrass (*Hilaria belangeri*) and black grama (*Bouteloua eriopoda*). For sagebrush lands, sand dropseed and fourwing saltbush (*Atriplex canescens*) are recommended (8, 14, 15).

Buffalo grass, though reproducing itself vigorously by vegetative means (Fig. 14, page 53), often gives poor results from seed because of low germination. It has been successfully propagated vegetatively by the use of small cubes of sod 4 inches square. These have been successfully scattered with a manure spreader, though this is not so sure a method as is placing the sods in the ground by hand. The sod blocks will

spread effectively over the area and completely occupy the land. When they were set 1 ft. apart, only 1 year was required to form a continuous sod; with a 6-ft. spacing, 5 years was sufficient (37).

The cool-season grasses found desirable for seeding include western wheatgrass, Canada wild rye (*Elymus canadensis*), Texas needlegrass (*Stipa leucotricha*), crested wheatgrass, and Texas bluegrass (*Poa arachnifera*).

Of the introduced species, King ranch bluestem or yellow bluestem (*Andropogon ischaemum*) in the southern parts and Caucasian bluestem

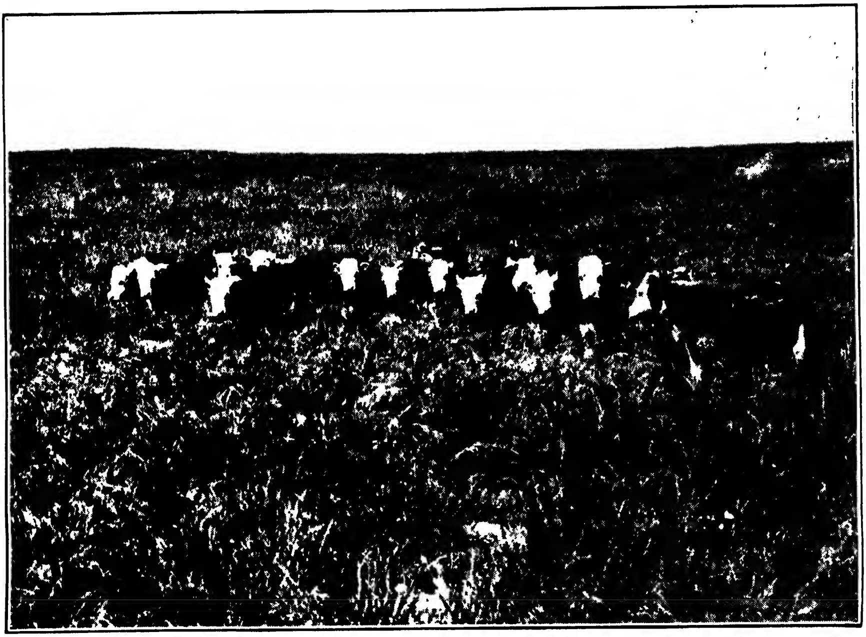

FIG. 136. Yearling steers on a pasture seeded to weeping lovegrass, Southern Plains Field Station. Six-year average steer gains were 139 lb. per acre, more than three times that of adjacent native range. (*U.S. Dept. of Agric. photograph.*)

(*A. intermedius caucasicus*) farther north in the area are outstanding (13). Others include weeping lovegrass (*Eragrostis curvula*) (Fig. 136) and angleton bluestem (*Andropogon annulatus*).

The Southwest. The Southwest is characterized by hot, dry climate. Though snow and low temperatures occur occasionally in the northern portions, some southern areas may be free from frost. Early-spring and late-summer rains are common, and it is these rather than temperature which determine growth in plants.

Only zones now supporting ponderosa pine, big sagebrush, woodland trees, or desert grasses are highly recommended for seeding (35). One of the main obstacles with which ranchers cope is rapid drying of the surface

soil; hence, it may be desirable to retard evaporation and protect the young seedlings by providing shade. This can be accomplished by scattering hay or straw over the barren areas after seed has been planted (3). Preparatory soil treatment is essential, although the lovegrasses occasionally succeed when broadcast on unprepared ground. Various implements to furrow or pit the soil have been developed to conserve water, and cultipackers mounted with seed hoppers are successfully used for planting loosened ground.

FIG. 137. Lehmann lovegrass seeded in southern Arizona, clearly the outstanding species for seeding arid sites in the Southwest.

Experimental work in the Southwest has shown rodent and rabbit damage to be so serious in many areas as to make seeding very difficult unless protection is provided (3, 52).

Experiments, generally, indicate that the best season for planting in the Southwest is May to July before the summer-rain season in the case of warm weather species but in fall or early spring in the case of cold weather plants such as *Agropyron* and *Bromus* (9). In mountainous areas, fall sowing is successful.

The arid semidesert lands at lower elevations in the Southwest are difficult to revegetate. Introduced species, chiefly lovegrasses, are most successful, but experiments have shown that the following native species sometimes do well on better sites (3, 4, 8, 14): sacaton (*Sporobolus wrightii*), spike dropseed (*S. contractus*), sand dropseed, giant dropseed (*S. giganteus*), alkali sacaton (*S. airoides*), curly mesquitegrass, tobosa-

grass (*Hilaria mutica*), galletagrass (*H. jamesii*), hairy grama, blue grama, black grama, fourwing saltbush, winterfat (*Eurotia lanata*), plains bristlegrass, Rothrock grama (*Bouteloua rothrockii*), and cottontop (*Trichachne californica*).

Of the introduced species, Lehmann lovegrass (*Eragrostis lehmanniana*) (Fig. 137) on the driest sites and Boer lovegrass (*E. chloromelas*) on somewhat more favorable sites, both introductions from Africa, are outstanding. These are seeded at a rate of 1 to 2 lb. per acre. Yellow bluestem (*Andropogon ischaemum*) also does well. They are highly

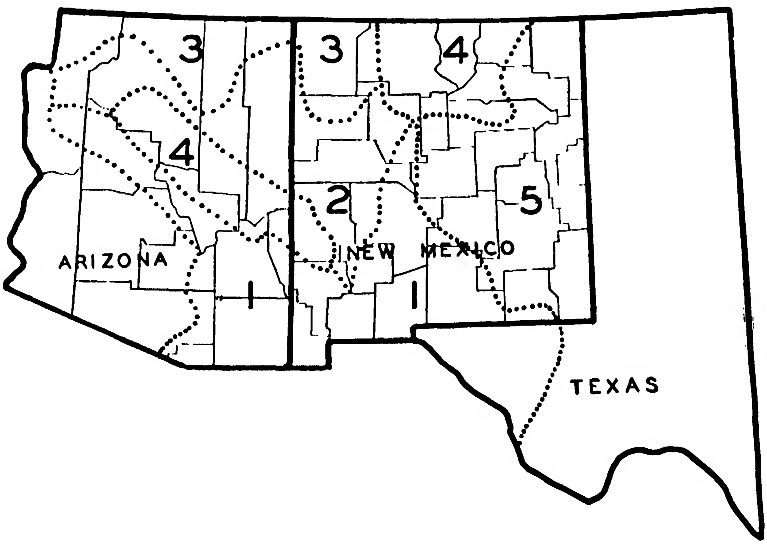

FIG. 138. Regions in the Southwest where various range forage species are adapted, as shown in Table 64. [*After Parker and McGinnies* (26).]

palatable, nutritious, and drought-resistant. On bottomlands, the lovegrasses, Johnson grass (*Sorghum halepense*), and blue panic (*Panicum antidotale*) are recommended.[1] Weeping lovegrass, although unsuited in hot, semidesert areas, is excellent in cooler and more humid sections (47). Because of its early growth, cold resistance, ease of starting, and low poundage of seed required per acre, it is proving an excellent species.

Native species that have been successful on mountainous ranges in the Southwest (10, 14, 35, 52) are slender wheatgrass (*Agropyron trachycaulum*), big bluegrass (*Poa ampla*), Arizona fescue (*Festuca arizonica*), pine dropseed (*Blepharoneuron tricholepis*), deergrass (*Muhlenbergia rigens*), muttongrass (*Poa fendleriana*), mountain muhly (*Muhlenbergia montana*), nodding bromegrass (*Bromus anomalus*), sideoats grama, and

[1] Reseeding desert grassland ranges in southern Arizona. *Ariz. Agr. Expt. Sta. Bull.* 249. 1953.

TABLE 64. RANGE FORAGE PLANTS ADAPTED TO THE SOUTHWEST, SHOWING WHERE AND HOW TO PLANT THEM
Data from Parker and McGinnies (26)

Common name	Botanical name	Regions adapted*	Seed per acre, pounds	Average yearly rainfall required, inches	Altitudinal limitations, feet	Depth to plant, inches	Site adaptation
Hairy grama	*Bouteloua hirsuta*	All	3–5	Above 12	Below 8,300	1	Loams, clays, sandy loams
Blue grama	*Bouteloua gracilis*	All	3–5	Above 12	Below 8,300	1	Loams, clays, sandy loams
Black grama	*Bouteloua eriopoda*	1, 2, 5	10–15†	8½–15	Below 6,500	½	Sandy soils
Side oats grama	*Bouteloua curtipendula*	1, 2, 4, 5	10–20	Above 10	Below 8,300	1	Loams, clays, rocky soils
Rothrock grama	*Bouteloua rothrockii*	1	5–10	10–15	Below 4,500	1	Sandy loams
Slender grama	*Bouteloua filiformis*	1	3–7	Above 10	Below 5,500	½	Sandy loams
Crested wheatgrass	*Agropyron cristatum*	2, 4, 5	3–7	Above 12	Below 7,500	1–2	Loams and sandy soils
Western wheatgrass	*Agropyron smithii*	2, 4, 5	8–15	Above 13	Below 8,000	1–2	Loams, clays, *ciénegas*
Slender wheatgrass	*Agropyron trachycaulum*	2, 4, 5	8–15	Above 14	Below 8,000	1–2	Loams, clays, *ciénegas*
Mesa dropseed	*Sporobolus flexuosus*	1, 2, 3, 5	2–4	8½–14	Below 6,500	½	Sandy soils and loams
Sand dropseed	*Sporobolus cryptandrus*	1, 2, 3, 5	2–4	8½–14	Below 6,500	½	Sandy soils and loams
Alkali sacaton	*Sporobolus airoides*	All	2–4	8½–14	Below 6,500	1	All soils, flood flats
Lehmann lovegrass	*Eragrostis lehmanniana*	1	2–4	10–15	Below 5,000	½	Sandy loams
Weeping lovegrass	*Eragrostis curvula*	1	3–5	10–15	Below 5,500	½	Sandy loams
Vine mesquite	*Panicum obtusum*	All	15†	8½–14	Below 6,500	½	All soils, flood flats
Smooth bromegrass	*Bromus inermis*	4	8–15	Above 13	Below 8,500	½	Loams
Big bluestem	*Andropogon gerardi*	5	7–12	Above 14	Below 6,500	1	Sandy soils and loams
Bermuda grass	*Cynodon dactylon*	1, 5	1–2†	....	Below 5,000	½	River benches, dirt tanks
Canada bluegrass	*Poa compressa*	2, 4, 5	5–10†	Above 17	Above 7,000	½	Loams, mountain meadows
Kentucky bluegrass	*Poa pratensis*	2, 4, 5	5–10†	Above 17	Above 7,000	½	Fertile lo ms, mountain meadows
Buffalo grass	*Buchlöe dactyloides*	5	1–2†	Above 15	Below 6,000	1	Loams, flood flats
Indian ricegrass	*Oryzopsis hymenoides*	1, 3	5–10	8½–12	Below 7,000	1	Sandy soils and loams
Tanglehead	*Heteropogon contortus*	1	4–6	10–20	Below 5,000	½	Sandy loams
Curly mesquitegrass	*Hilaria belangeri*	1, 5	5–10	Above 15	Below 6,000	½	Sandy loams, loams, clays
Tobosagrass	*Hilaria mutica*	1	5–10	8½–15	Below 5,000	½	Heavy soils, flood flats
Galletagrass	*Hilaria jamesii*	2, 3, 4, 5	5–10	8½–15	Below 7,000	½	Loams, clays, flood flats
Fourwing saltbush	*Atriplex canescens*	1, 2, 3, 5	12–15	8½–15	Below 7,000	½	Flood flats, deep soils
Winterfat	*Eurotia lanata*	1, 2, 3, 5	5–10	8½–15	Below 7,500	½ or less	Loams, sandy soils
Shadscale	*Atriplex confertifolia*	3	15–18	8½–15	Below 6,500	1	Heavy soils, flood flats
Alfilaria	*Erodium cicutarium*	1	3–5	10–15	Below 6,000	½	Sandy loams

* See Fig. 138 for regions.
† Or transplant by sod.

spike muhly (*Muhlenbergia wrightii*). Introduced species that are well adapted include crested wheatgrass, intermediate wheatgrass, orchardgrass (*Dactylis glomerata*), tall oatgrass (*Arrhenatherum elatius*), and smooth bromegrass. A summary of species and seeding conditions for the Southwest is shown in Table 64.

The Intermountain Region. The intermountain region receives predominantly winter precipitation, deep snows being common at higher elevations and on many of the lower lands. The variable topography of the region results in great diversification of precipitation from area to area, and long drought periods are of frequent occurrence.

FIG. 139. Tall wheatgrass after 8 years on dry land of central Utah. This species also is excellent on wet and saline soils where it reaches heights of 6 ft.

Very early spring or late fall are the preferred seeding seasons on low-elevation ranges; however, early fall also may be successful, especially at high elevations.

Low-elevation ranges generally are too arid for any but the most drought-resistant species. Crested wheatgrass, seeded alone, is most popular (45), but intermediate wheatgrass and stiffhair wheatgrass (*Agropyron trichophorum*) are recommended. Removal of sagebrush is a major problem on these areas (see page 345). Downy bromegrass (*Bromus tectorum*) where abundant also must be eliminated by fallowing or deep plowing.

On wetter lands, especially salty lands, tall wheatgrass (*Agropyron elongatum*) and tall meadow fescue (*Festuca elatior*) are favored.

On piñon-juniper lands, crested wheatgrass has been clearly outstanding, although on more favorable parts stiffhair wheatgrass, tall wheatgrass (Fig. 139), intermediate wheatgrass, and sweet clover are also successful (16).

At high elevations, growing conditions are much better and smooth bromegrass (Fig. 140), tall oatgrass, alfalfa, orchardgrass, timothy, and Kentucky bluegrass are among the best species (Table 65). In western

FIG. 140. Smooth bromegrass (*Bromus inermis*) has surpassed all other species for seeding high-elevation ranges in the intermountain region.

Colorado at 7,600 ft. elevation under an average precipitation of 18 inches a mixture of 2 to 3 lb. alfalfa, 6 to 8 lb. smooth bromegrass, and 5 to 7 lb. crested wheatgrass was best (20). At still higher elevation (8,000 to 10,500 ft.), an excellent mixture for grassland parks is 2 lb. each of timothy and orchardgrass plus 3 lb. each of smooth bromegrass and intermediate wheatgrass (7). Under aspen, timothy and orchardgrass alone are best, and in drier brush sites crested wheatgrass, intermediate wheatgrass, slender wheatgrass, and tall wheatgrass are outstanding.

TABLE 65. SPECIES AND SEEDING RATES RECOMMENDED FOR THE INTERMOUNTAIN AREA UNDER DIFFERENT RANGE CONDITIONS
Data from Interagency Committee (17)

Site	Method of seeding*	Crested wheatgrass	Intermediate wheatgrass	Tall wheatgrass	Western wheatgrass	Tall fescue	Yellow sweet clover	Russian wild rye	Blue bunch wheatgrass	Tall oatgrass	Smooth bromegrass	Alfalfa	Orchardgrass	Mountain bromegrass	Timothy	Total rate, pounds per acre
Sagebrush or cheatgrass cover:																
Less than 12 inches precipitation; all soil conditions	D	6														6
	B	10														10
More than 12 inches precipitation; light and medium soils	D	3	3	2												8
	B	5	5	2												12
More than 12 inches precipitation; heavy compact soils	D	2	2	2	2											8
	B	4	3	3	3											13
Salty lands:																
Wet, salty land with high-water table	D			4		4	2									10
	B			6		4	4									14
Dry, salty land with deep-water table	D			6				4								10
	B			8				6								14
Mountain brush cover:																
Dry to fairly moist; no brush, no shade	D	2	3						3							8
	B	3	5						4							12
Deep soils, above average moisture; no shade	D		2							2	2	2				8
	B		3							3	3	3				12
Brushy, shady areas, steep slopes	B									4	4		3	4		15
Aspen cover:																
Deteriorated ranges	B									3	5		3	3	2	16

* Method of seeding: Drilling (D). Broadcast (B).

Abandoned farm lands of southern Idaho are best seeded to crested wheatgrass, blue bunch wheatgrass (*Agropyron spicatum*), and tall wheatgrass in pure stands, so they can be grazed separately (42).

Common fall rye seeded at 40 to 50 lb. per acre is a popular livestock forage in some areas (45). It is excellent early feed and is grazed in fall

also, after grain has matured. The annual character of this plant makes occasional reseeding necessary, although volunteer plants may continue for 10 years. Rye and other grains are good emergency feeds for such uses as carrying livestock, while other parts of the range are being seeded to perennial grasses.

The Pacific Coast. The Pacific Coast region is characterized by heavy precipitation and warm temperatures, but prolonged drought may occur in the hot summer months. Competition with other vegetation is severe in the coastal region because of the excellent growing conditions during at least part of the year. For this reason, except following a burn, it is important to prepare a good seedbed.

In northern parts of the Pacific Coast region, fall seeding has proved preferable. In southern parts, early spring is more successful (40). Where soil preparation is poor, fall seeding is always best (19).

On the northern Pacific slopes, a great variety of grasses and forbs thrive. The following mixtures are recommended for various situations (40), though many other species have given good results:

	Pounds per Acre
For moist bottom lands:	
Italian ryegrass (*Lolium multiflorum*)	3
Perennial ryegrass (*Lolium perenne*)	3
Meadow fescue (*Festuca elatior*)	4
Kentucky bluegrass (*Poa pratensis*)	4
White clover (*Trifolium repens*)	2
Red clover (*Trifolium pratense*)	2
Alsike clover (*Trifolium hybridum*)	2
Total	20
For fertile uplands:	
Italian ryegrass (*Lolium multiflorum*)	4
Tall oatgrass (*Arrhenatherum elatius*)	4
Orchardgrass (*Dactylis glomerata*)	4
Kentucky bluegrass (*Poa pratensis*)	4
White clover (*Trifolium repens*)	2
Red clover (*Trifolium pratense*)	2
Alsike clover (*Trifolium hybridum*)	2
Total	22
For lands subject to flooding for short periods:	
Seaside bentgrass (*Agrostis palustris*)	5
Meadow foxtail (*Alopecurus pratensis*)	5
Italian ryegrass (*Lolium multiflorum*)	4
Alsike clover (*Trifolium hybridum*)	4
Total	18
For lands subject to flooding for long periods:	
Reed canarygrass (*Phalaris arundinacea*)	8–12
Seaside bentgrass (*Agrostis palustris*)	8–10

On California coastal ranges, Harding grass (*Phalaris tuberosa* var. *stenoptera*), tall fescue, orchardgrass, burnet (*Sanguisorba minor*), birdsfoot trefoil (*Lotus corniculatus*), and annual clovers, including subterranean clover (*Trifolium subterraneum*), rose clover (*T. hirtum*), and crimson clover (*T. incarnatum*) have proved valuable (22). Fertilization has been found to aid establishment and maintenance of seeded forage where competition of resident annuals can be controlled (see also page 415).

Revegetation is difficult in the southern parts of the coastal region because of the severe competition furnished by the annual plants which effectively occupy almost all the area (Fig. 20, page 60). The establishment of perennials is desirable, for the annual grasses are of low feed value during the dry summer and fall periods, whereas perennials are able to remain green for a longer period and to maintain their nutritive value at a higher level when dry. A mixture of annual clovers, including subterranean clover, rose clover, and crimson clover, is a good understory for veldtgrass (*Ehrharta calycina*) and smilo (*Oryzopsis miliacea*). Harding grass is added on better sites (22).

Seeding into stubble of annual grasses generally results in failure, however, seeding into stubble of Sudan grass rather than fallowing is generally successful. The success of Harding grass seedings is governed by degree to which land preparation and previous crop treatment suppresses resident annuals (24).

Many foothill ranges, especially in California support dense stands of root-sprouting brush (Fig. 26, page 70). These sites usually have good soil and, if brush is removed by burning or mechanical means (see page 341), seeding often is necessary in spots which do not have native grasses (22). Broadcast seeding in the ash immediately after brush burns, preferably before fall rains, has proved satisfactory. Both perennials and annuals are used. A proved mixture for general use, at 5 to 8 lb. per acre, includes 1 part Italian and perennial ryegrass, 1 part orchardgrass, 1 part tall fescue, 1 part smilo (*Oryzopsis miliacea*), 3 parts annual clover (*Trifolium subterraneum*, *T. hirtum*, and *T. incarnatum*), 3 parts alfalfa, and 5 parts Harding grass (22).

Sudan grass, grown both dry and irrigated in the central valleys of California, has been successful as a source of green feed in summer (19). On higher mountains, crested wheatgrass, tall oatgrass, orchardgrass, smooth bromegrass, alfalfa, sweet clover, and ryegrasses are recommended (19). Redtop and bulbous bluegrass (*Poa bulbosa*) also are successful (10). Experiments on burned cutover forest land indicate that various species of bentgrass, fescue, lotus, and clover will give good success when broadcast into the ashes as soon as they are cold. Heavy grazing after maturity is possible on these areas; and, in many places, heavy grazing of sod-

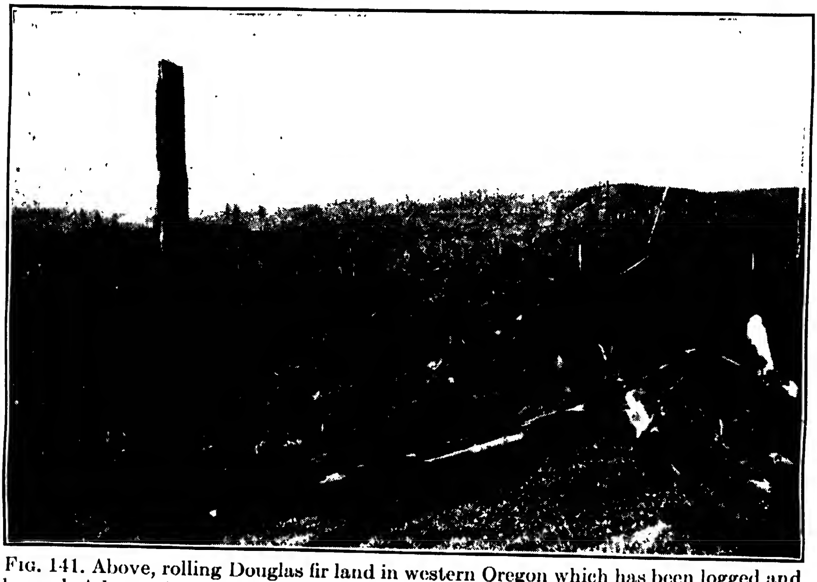

FIG. 141. Above, rolling Douglas fir land in western Oregon which has been logged and burned. A heavy bed of ashes results. Burning such lands after logging is required by law. Below, a similar area which has been seeded by airplane directly into the ashes after burning. Such land has a grazing capacity of more than 1 sheep per 1½ acres. (*Photographs by R. G. Johnson.*)

forming grasses by sheep seems actually to assist in keeping brush from invading the seeded areas (Fig. 141).

The flat pea (*Lathyrus sylvestris*) is a promising species for the West coast mountains (12) because of its high palatability and aggressiveness against heavy competition from bracken fern. There is, however, some danger of sheep being poisoned by this plant.

The Northwest. The northwest region includes the coniferous-forest land of western Montana, northern Idaho, and Washington and Oregon, except the West coast. Most of this region has a precipitation adequate to support a number of forage species, but precipitation is highly variable, making difficult general recommendations. The white pine forest may average nearly 60 inches of precipitation contrasted with perhaps 10 to 15 inches on ponderosa pine-sagebrush types. Heavy snows are characteristic, most of the precipitation coming in this form.

Seeding is generally done on cutover forest lands, most of which are burned after the cutting. Because of the litter on the ground, most seeding is done by broadcasting, though the use of a drill is desirable where conditions permit because of the better distribution of seed so obtained (5). Skid trails and other accessible parts often are seeded by power-driven implements from the ground, but inaccessible parts are seeded from airplane. On areas which have been clean-burned by hot fires to destroy competing plants, these plantings generally are highly successful.

It is important in seeding burned forest land to plant the seeds as soon as possible after the fire, for weed species very soon offer overpowering competition (5). If weeds and brush are allowed to gain a foothold, they effectively keep out the grass. Once established, however, grass seems to compete successfully with the invading plants, provided it is grazed in a manner that keeps the cover intact.

Time of seeding apparently is not a decisive factor in obtaining a stand of forage on burned-over mountain ranges in northern Idaho where moisture is plentiful. There was no appreciable difference found among seedings made on snow, on honeycombed ground after the snow had disappeared, in late spring, or in the fall (5). Spring seeding has proved best in Montana mountains (41).

Various investigators (10, 12, 14) have found that the following species give promising results: tall meadow fescue, sheep fescue (*Festuca ovina*), bulbous bluegrass, white clover (*Trifolium repens*), slender wheatgrass, blue bunch wheatgrass, nodding bromegrass, Idaho fescue (*Festuca idahoensis*), mountain bromegrass (*Bromus carinatus*), smooth bromegrass, crested wheatgrass, Canada wild rye, big bluegrass, Sandberg bluegrass, timothy, and subterranean clover (*Trifolium subterraneum*). In western Montana mountains (41), tall oatgrass, orchardgrass, intermediate wheatgrass, stiffhair wheatgrass, Russian wild rye (*Elymus

junceus), and big bluegrass are especially successful. On burned timberland, orchardgrass, timothy, bulbous bluegrass, Kentucky bluegrass, tall oatgrass, and smooth bromegrass are recommended (11).

At very high elevations in Montana (32), the most successful species are smooth bromegrass, meadow foxtail (*Alopecurus pratensis*), Kentucky bluegrass, meadow bromegrass (*Bromus erectus*), bearded wheatgrass (*Agropyron subsecundum*), and slender wheatgrass.

The Southeast. The southeast ranges have adequate precipitation and favorable winter temperatures to permit growth of a wide variety of grasses. Poor soils and high summer temperature are limiting factors, and soil fertilization may be necessary for optimum production.

Native grasses usually grow with such vigor and abundance that artificial seeding has not been widely practiced except on a semipasture basis. Destruction of native cover often is difficult. Burning in spring to clear away native grasses sometimes is helpful but usually should be followed by a heavy disk or plow. Various brush-chopping machines have been developed to dispose of the rank growth characteristic of many areas.

Warm-climate grasses successful as pasture plants are Bermuda grass (*Cynodon dactylon*), Rhodes grass (*Chloris gayana*), Bahia (*Paspalum notatum*), Dallis grass (*Paspalum dilatatum*), Johnson grass (*Sorghum halepense*), Harding grass, carpetgrass (*Axonopus affinis*), St. Augustine grass (*Stenotaphrum secundatum*), Napier grass (*Pennisetum purpureum*), and, in warmer parts, paragrass (*Panicum purpurascens*). Promising legumes include the many species of *Lespedeza*, vetch, crimson clover, white Dutch clover, hop clover, and kudzu (*Pueraria thunbergiana*). For more temporary pastures ryegrasses, Sudan grass, rescuegrass (*Bromus catharticus*), and various small grains are recommended.

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CHAPTER 16

RANGE IMPROVEMENTS

Ranges producing their potential maximum are rare in the West. Originally, good forage was abundant over most of the range area, but this frequently has been altered by years of heavy grazing. Despite these years of use, much of the land has not been improved or developed, but, instead, low-cost production under natural conditions is a common practice.

Better use of range land has been discussed in Chap. 13 wherein it was pointed out how more uniform utilization results in increased production. Developing range land by eradicating undesirable plants and by seeding grasses has been discussed in Chaps. 14 and 15. Additional methods of improving range lands to increase production and secure uniform utilization are discussed in the present chapter.

Low production often is caused by insufficient, inadequate, and poorly distributed water holes. Especially on rough topography, where animals tend to overuse the most accessible areas, insufficient fencing may be a major range problem. Loss of water by runoff may be minimized by proper range improvement and the water used to produce an increased forage yield. In some areas range fertilization also may increase both the amount and the quality of forage available. Although these devices are not applicable to every range, taking advantage of such improvement techniques as are useful is necessary to maximum production from ranges.

WATER DEVELOPMENTS

Perhaps the most important range-improvement program needed in the West is the development of stock-watering facilities (Fig. 142). Many ranges normally are not supplied with water adequate for best grazing use. Although this generally is not true of high mountains where rivers and springs are abundant, desert and foothill ranges may be without water over much of their area. If these lands are to receive full use, it is necessary that sources of water be developed or that water be hauled to the animals. On many desert ranges, developing a source of water is economically or physically impossible. Some of these are used

only in winter when animals can use snow to quench their thirst. Others may be used by hauling or piping water from elsewhere. A few are unused.

The advantages of better and more adequate watering facilities are evident. Monetary returns from the use of the range are dependent upon meat production. If animals are required because of the scarcity of sufficient watering places to travel long distances to and from water, gains and hence profits cannot be maximum.

Range animals can be made to travel excessive distances for water, cattle being known to travel regularly distances of 5 or even 10 miles. This situation is not satisfactory, for it results in excessive trampling,

FIG. 142. Stock-watering facilities are essential to much western range land. Plenty of good clean water is of great benefit to livestock.

excessive expenditure of energy, and reduced feeding time. Under such conditions, cattle water infrequently. Cows, as a result, cannot produce a normal milk supply, which, in turn, results in smaller calves.

The improper distribution of watering places causes congregation of animals and excessive grazing in the vicinity of existing water. The areas farthest from water are reached only by active and adventurous animals. The consequence is that the herd uses only a fraction of the range. Utilization varies from destructive near the water to none at great distances, use on level land being in proportion to distance from water (Fig. 113, page 325). Unused forage resulting from insufficient water was common in the early stages of the range industry when forage was abundant, but under present range conditions such wasteful practices should no longer be tolerated.

By increasing the number of watering places, livestock distribution is made more uniform, and grazing pressure is relieved at points of concentration (Table 66). This ordinarily results in increased carrying capacity of the range because under heavy use, areas around watering places may contribute little or no forage to the livestock, and those distant from water do not contribute their potential quantity. If proper distribution is obtained, damage to plants is minimized. Though some misuse around water is inevitable, the damaged area should never comprise a high percentage of the total range area.

TABLE 66. PERCENTAGE OF RANGE AREA RECEIVING VARIOUS DEGREES OF GRAZING UNDER GOOD AND POOR WATERING CONDITIONS
Data from Talbot (34)

Degree of grazing	Better watered	Poorly watered
Overgrazed	8	29
Moderately to closely grazed	69	44
Lightly grazed	19	19
Practically unused	4	8

Increased water development all too often is used not as a means of effecting better distribution but as a means of crowding more animals upon an already overstocked range. The general range deterioration actually may be aggravated by increased water development because this may result in an increased number of concentration areas unless a proper stocking policy is followed.

Number of Watering Places Needed. The number of watering places necessary is variable and will depend upon local conditions. The various kinds of livestock differ somewhat in the distances that they can travel from water, and these distances depend, in turn, upon the topography. Sheep and goats may need only half the number of water developments that are required for cattle. Not only can they go longer without water but, because they are herded, they can be made to graze farther from the source of water without damaging the range. Actually, cattle, and especially horses, can move out from water farther within a given time than can sheep, but they show a greater reluctance to move away from the water after they have satisfied their thirst.

In excessively steep and rough country, cattle should not be forced to go more than 1/2 mile for water, though in more level areas this can be measurably increased. Even in flat country they should not be expected to travel more than 2 1/2 miles. This would require water holes 1 to 5 miles apart and one source might serve 1 to 20 sections of land, depending

upon the topography. These distances would apply equally well to sheep when they are watered daily but would not apply when longer periods elapse. Where insufficient water is available at each source to supply the stock within the radius of effective grazing, amount of water, and not distance stock can travel, becomes the criterion of adequacy.

Water Requirements of Range Livestock. The water requirements of livestock depend upon (*a*) the kind of stock, (*b*) the nature of forage, and (*c*) weather conditions. If the forage is green and succulent, the amount of water needed will be much less than if the feed is dry. Studies in Nebraska (32) have shown that range plants in the spring contain over 80 per cent water, whereas the same species by midsummer contain 40 per cent or less. A cow consuming 20 lb. per day dry weight receives 50 to 100 lb., or 6 to 12 gal., of water. Considerably more water is required by livestock when the temperature is high and the humidity low, because both these factors cause water losses from the body to be high (31).

Studies with milk cows under controlled temperatures showed that the average daily water consumption increased by 6, 17, and 50 per cent over that consumed at 60°F. when temperatures were raised to 70°F., 80°F., and 90°F., respectively (35), although there is considerable variation in data on this point (25).

Experiments on salt-desert winter ranges (15) showed sheep to drink an average of 0.72 gal. per day. On especially dry feed, consumption was 1.5 gal.; on very salty feed, consumption was 1.8 to 2.2 gal.; and in warmer spring months, consumption averaged 0.86 compared with 0.63 in colder winter months.

TABLE 67. AVERAGE WATER REQUIREMENTS OF HORSES, CATTLE, AND SHEEP PER DAY

Horses, gallons	Cattle, gallons	Sheep, gallons	Authority
10–12	10	0.25–1.50	Henry and Morrison (12)
10	10	1	Talbot (34)
.....	6.3	....	Stanley (31)
.....	7.75	....	Talbot*
.....	.....	0.36–0.375	Ingram (16)
.....	.....	0.75–0.84	U.S. Sheep Expt. Station (1)
.....	.....	0.72	Hutchings (15)

* Personal correspondence. Data from Burgess Spring experimental range in northern California, a 6,000-ft. plateau in the ponderosa pine type.

In view of the various conditions affecting water usage, precise recommendations are hazardous. The consumption records shown in Table 67 serve as approximate guides upon which development plans can be based.

The figures given by Ingram (16) for the Northwest are remarkably low, being about 1½ qt. daily for a ewe with lamb. This was hauled to the animals on tank trucks; it is possible that the consumption was slightly lower than where the animals have easy access to water. The consumption found for cattle by Stanley (31) was also low considering the comparatively arid conditions of the Southwest. Cows with calves averaged but 6.3 gal. per day, ranging from 2.6 gal. in the winter to 11.5 gal. in the summer. Although it likely is wise to provide livestock with adequate amounts of water, research indicates that possibly most recommendations are rather more than actual requirements.

Mule deer in Utah have been found to consume 1⅔ qt. daily during summer (30). This is somewhat lower than was observed in Arizona (22).

Frequency of Watering. Of the domestic stock, cattle require water more regularly and should be watered every day for best results. Horses and sheep show satisfactory progress under less favorable water conditions. Frequently, horses water only at 3-day intervals when the vegetation is succulent. Under usual conditions, sheep are watered at least every second or third day but preferably daily. Sheep on salt-desert range in winter were found to gain 3.4 lb. when watered daily for 40 days and 0.8 lb. when watered each second day, but when watered each third day, they lost 6.0 lb. (15). Sheep watered daily grazed more quietly, ate a greater variety of feed including dry material, and utilized the range more uniformly.

Under adverse conditions, grazing sheep for relatively long periods without access to water is possible and is a common practice where forage is succulent. In Montana (17), sheep were grazed with absolutely no watering for the three summer months. The lambs gained 0.23 lb. per day, which compared favorably with those produced on well-watered range. Similar results were obtained on high mountain ranges in central Utah. Conclusions from these studies were as follows: (*a*) On succulent weed ranges in high mountains, sheep can be grazed without water with gains comparable with those from well-watered ranges. (*b*) On nonsucculent grass range in high mountains, sheep can do well if they get a limited amount of moisture in the form of dew, fog, or rain. (*c*) Rarely is it necessary to drive sheep long distances to water on mountainous summer ranges oftener than every third day. (*d*) Where water is inadequate, quiet open grazing and shading up during the hot midday is imperative.

The government farm at Graaff-Reinet, South Africa, has reported a band of sheep being grazed for 3 years with no water save that obtained from succulent cacti. Lamb and wool yields were perfectly normal. When offered water after 3 years, many animals refused to drink!

Grazing sheep on winter ranges without water is common practice

where the animals have access to snow. Thousands of acres of range with no water development whatever are used in this manner, though in winters of deficient snow it becomes hazardous.

Quality of Water. It ordinarily is not necessary to consider the quality of water for use by livestock, although, in some arid regions, minerals may make water unfit for consumption. Bad water was a source of terror to the early explorers and travelers in the western deserts. Heller (10) in studying the effects of salinity of water upon animals found that both sheep and cattle refused salt water if fresh were available, even after having become accustomed to salty water. If limited to very salty water, they refused supplemental salt. The kind of salt seemed to influence but slightly the reaction of the animal, but the total soluble salt was very important. Sheep were able to exist on water containing 2.5 per cent sodium chloride and cattle not in milk, on water containing about 2.0 per cent. For general conditions, however, a total of 1.5 per cent was considered the limit of salt in drinking water under which maintenance could be expected.

Dirty water does not seem to be injurious to livestock, although care should be taken to keep it as clean as possible.

Algae may be kept from growing in water tanks and troughs by the use of copper sulfate. This salt is harmless in small amounts to livestock, yet as little as 1 p.p.m. will prevent algae growth. Since the salt dissolves slowly, a few crystals may be placed in a bottle fitted with a cork having a small slot cut in the side. This bottle is placed in the trough and the copper sulfate allowed to pass slowly from the bottle (36).

Types of Water Development. The type of development best suited to a range will depend upon local conditions (Table 68). It is cheaper to

TABLE 68. PERCENTAGE DISTRIBUTION OF WATER-DEVELOPMENT COSTS IN UTAH AND OREGON

Data from Oregon State Planning Board (23) *and Utah Emergency Relief Administraion* (18)

State	Type of development	Labor	Material	Hauling and drilling	Contin-gencies
Oregon	Wells	42	49	..	9
	Springs	73	18	..	9
	Reservoirs	72	19	..	9
Utah	Wells				
	Cased	11	49	40	
	Uncased	10	16	74	
	Springs	57	32	11	
	Reservoirs	64	8	28	

develop springs and seeps, where they exist, than it is to dig wells, since the water table generally is at considerable depth on dry ranges. There are exceptions to this, for good wells exist even in very dry areas at reasonable depths, instances of 20-ft. wells being known. Unfortunately, the number of springs and seeps is limited by nature. Even on mountain ranges, a shortage of surface water in the dry West is not rare.

If neither spring nor seep is available, wells or reservoirs generally are used. Each of these has certain advantages and disadvantages, and the two often are used to supplement each other on the same range. Small reservoirs are more cheaply constructed than wells, but they have the disadvantage of being dependent upon surface runoff from rains or melting snows. Though generally more expensive both in initial cost and in upkeep, wells are usually reliable the year around, and on foothill and semidesert ranges where other sources cannot be relied upon they become a necessity.

Springs. In spring development, a curbing or collection box is desirable. Concrete, stone, or wood may be used to construct the box. Where possible, this curbing should extend down to bedrock or to the source of the water. Where the water arises from a layer of unconsolidated material, however, and the area is boggy, this may be impracticable. Tile drains may be laid in order to assist in water collection if there is but a small amount of water present. The tile should radiate out from the spring box at angles to increase its effectiveness. Where springs occur on solid ground, digging toward the source of the flow and filling with coarse rounded rocks from which the flow pipe leads is satisfactory. The rocks are covered with gravel, the gravel with sand, and the sand with fine soil so that the spring is completely covered.

Where the flow of water is great and there is additional water welling up around the spring box, making a soft boggy area, it is well to provide a fence to prevent stock from trampling the area. Where water supply is limited and the water is all collected in the spring box, it may be advantageous to pipe the water some distance from the source and leave the area unfenced. In this case, the box must be covered. Such a spring site may remain relatively dry, and stock trampling will be of little consequence. Furthermore, grazing the area prevents heavy growth of vegetation, thus saving water and lessening likelihood of roots entering and clogging the tile.

Wells. Wells are more expensive than other water developments and require more care and upkeep, but they are necessary on many ranges. Where the water table is deep and few springs exist, wells may be the only development feasible. In the Southwest, grazing on many of the high plateaus would be impossible without this type of development.

Wells may be of several kinds. Where the water is near the surface,

wells may be dug by hand, though only in certain types of soil is this practicable. Twenty-five to fifty feet is about the limit of depth for a dug well. Wells may be driven by means of a perforated pipe with a special hardened point, provided that the soil is not too impervious. Where conditions permit, the driven well offers a cheap source of water, though the capacity is often small. Wells may be bored by a special auger where the soil is free from rock. The most common type of well, however, is the drilled well, which may be used in areas where the soil is rocky and

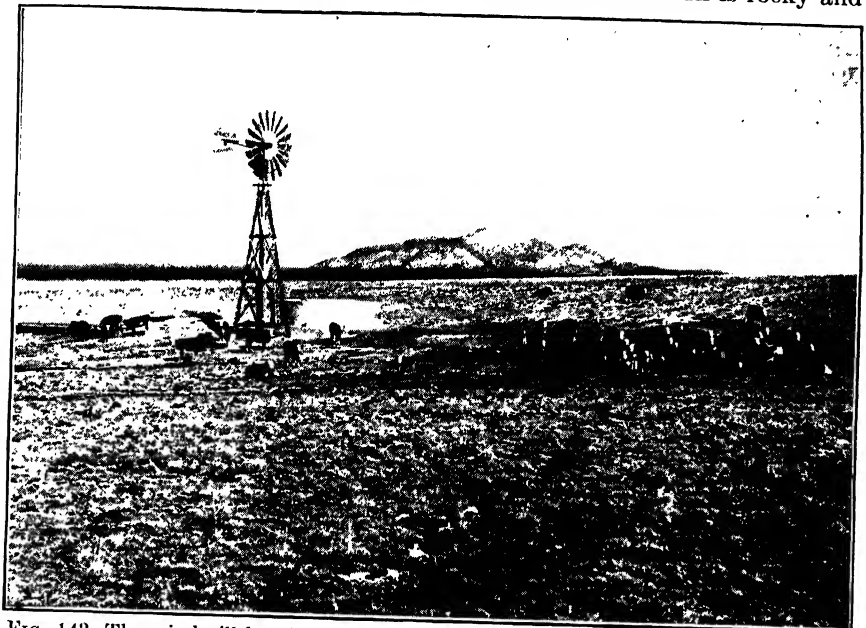

FIG. 143. The windmill has for years been the source of power in the West and has become almost symbolic of the windy plains. This water development in New Mexico includes the windmill, a 20,000-gal. storage tank, and troughs. (*Courtesy of U.S. Bureau of Land Management.*)

where water is at great depths. Drillers charge by the foot for this type of work; hence, the deeper the well, the greater the cost. Moreover, the cost per foot increases with greater depth of drilling. The nature of the underlying strata is also important, rock formations greatly adding to the cost of drilling. A saving is achieved, however, in materials, for such wells may be left uncased.

Pumping Equipment. Windmills and gasoline engines are common sources of power (Figs. 143 and 144). Each of these has certain advantages. In general, windmills are satisfactory in the West because winds are common enough to supply the power needed. However, where winds are uncertain, the windmill without storage facilities is not reliable. Windmills are advantageous in that they operate with little care and no

FIG. 144. A typical water development powered by gasoline pump. The pump and engine are housed in the small building. A 35,000-gal. storage tank and trough complete the equipment. (*Courtesy of U.S. Bureau of Land Management.*)

FIG. 145. A combination storage tank and watering trough fed from a well by automatic float valve. (*Courtesy of U.S. Bureau of Land Management.*)

fuel. They usually need not be greased or repaired oftener than once or twice a year. This is a distinct advantage on the range where it is inconvenient to inspect at regular intervals.

Gasoline pumps require constant attendance when they are operated. For this reason, they are not so practical, except, perhaps, in the immediate vicinity of dwellings. Even in such locations, it may be profitable to have a windmill as well and use the gasoline engine only when winds fail.

Troughs and Storage Tanks. The number and size of the storage tanks needed depends upon the type of development and number of livestock

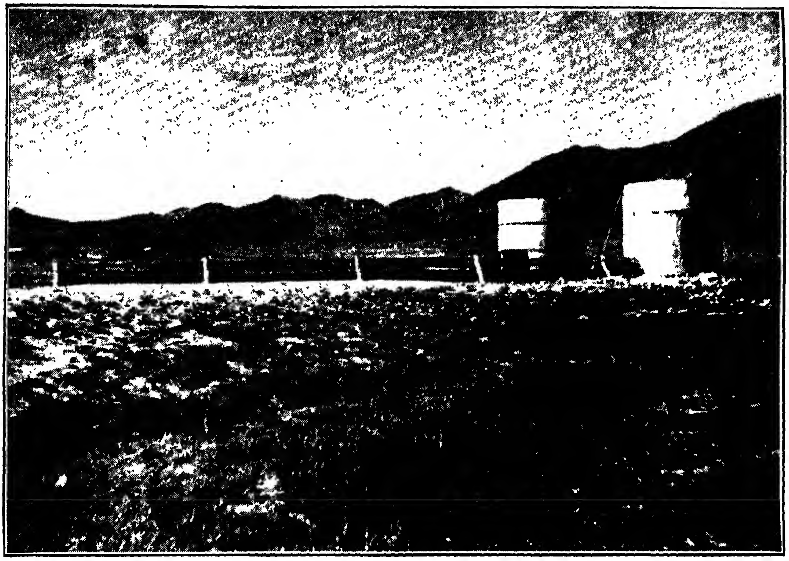

FIG. 146. A cement trough and storage tank. Water is supplied by gravity from a spring located in the hills in the background.

using them. If the well can be pumped at will, the size of the tanks need not be in excess of the immediate demands of the stock likely to water at one time. For sheep, the tank will normally need to be larger than for cattle, since the size of the herd using it at one time is larger. It is recommended that troughs of a length not less than 75 ft. be used for sheep; for cattle a 10-ft. trough ordinarily is adequate.

The demand for water during certain periods may exceed capacity of the trough, particularly where windmills are used and winds may not occur for several days. In such cases, storage facilities should be provided to supply the demand over calm periods. Tanks connected to the trough by an automatic float device are used. This provides for the trough being full at all times as long as there is water in the storage tank. A combination storage tank and watering trough is shown in Fig. 145.

Storage tanks may also be used in connection with spring developments where the flow is too low to supply sufficient water in a short period (Fig. 146). For example, a spring flowing 1,500 gal. every 24 hr. would be insufficient to water a large band of sheep unless the water were collected in a tank so that it could be delivered promptly when needed.

Many types of trough have been used successfully. Whether metal, hewn-log, or wooden-plank types are used is largely a matter of avail-

FIG. 147. A metal watering trough for sheep. Note the heavy supporting posts.

ability of material and cost. Any of them, if carefully installed, will be satisfactory, but experience indicates that metal troughs are best. They should be constructed from heavy metal, 16 gauge being desirable, and should be well reinforced at the edges with angle iron or strong lumber.

Whatever type is used, there should be adequate support for the trough (Fig. 147). Water is heavy. The approximate weight of water in pounds can be computed by multiplying the capacity of the trough in gallons by 8.

An inexpensive support can be made from posts firmly set in the ground, with crosspieces between them upon which the trough rests or

short logs laid crosswise on the ground underneath the trough (Fig. 148). More expensive but also more permanent supports can be made from concrete. In any case, supports should rest on solid ground to prevent unequal settling. If the trough is long, the cross supports should be at frequent intervals to relieve the trough itself from undue strain.

Whether or not the overflow water is to be used in another trough, there should be an adequate standpipe to carry the excess water away. To prevent clogging of the overflow pipe, the top of the standpipe should

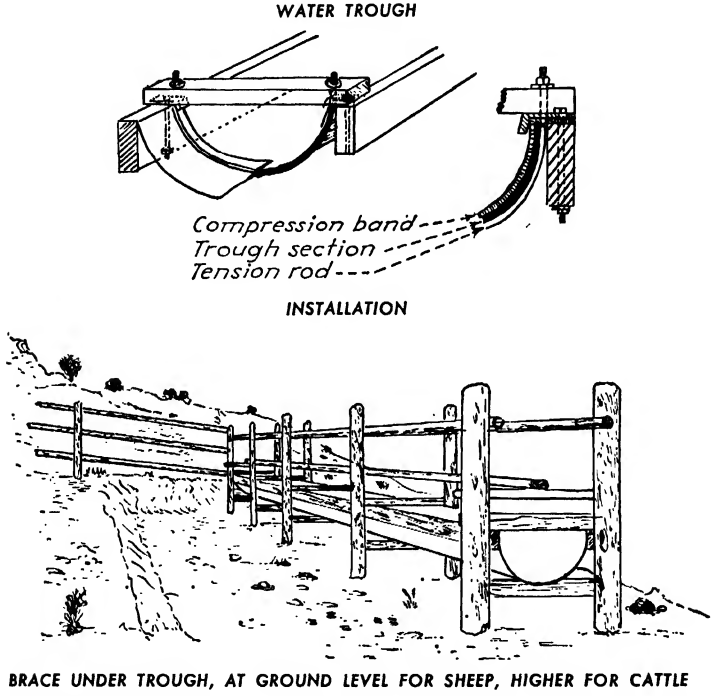

Fig. 148. Adequate support for a water trough is important. The trough should be heavily reinforced at the edges and rested upon a firm foundation of logs. (*After U.S. Forest Service.*)

be provided with a U-pipe having a hole bored in the top. Debris does not readily enter and clog such an overflow.

Reservoirs. The reservoir, though somewhat limited in adaptability, is of great importance in range-water development. Its disadvantage lies in the fact that it depends upon surface runoff or seepage and may be empty when most needed, as in times of drought or in dry seasons of the year. It has the advantage of being cheap to construct.

Important considerations in reservoir construction are the losses from evaporation and underground seepage. It should be ascertained that the

soil will hold the water impounded or that there is an impermeable layer underneath the surface, before the construction of a reservoir is undertaken. Heavy clay or adobe soil is ideal for reservoirs; indeed, hauling in material of this kind where it is not already present and scattering it over the bottom of the structure will do much to plug leaks. Various commercial products have been used with some success to seal the bottom of leaky reservoirs, though the cost is increased materially by such a practice. Bentonite, a clay material with a high colloidal content, is widely used. Regardless of the soil texture, reservoirs are likely to leak

FIG. 149. Rough rock covering on the upper face of a dam prevents cutting from wave action. Structures of the type shown here serve as a combination gully control and stock-water source. (*Courtesy of U.S. Soil Conservation Service.*)

at the first filling unless the soil is puddled. This can be accomplished by wetting the bottom and using livestock to trample the area.

In calculating potential stock-watering capacity, attention must be given to evaporation losses. Calculations indicate that the annual loss varies from 70 inches along the southern border to 20 or 30 inches along the northern border of the western United States (3). This emphasizes the importance of building reservoirs deep and with small surface area. The use of covered cisterns, though expensive, may be justified where water is scarce.

Recently a water-catchment device known as the *guzzler* has come into common use in the Southwest, to provide water for game animals which seems to offer some promise as a range water facility. This consists

of a sloping fan-shaped concrete or asphalt surface set just above ground level with a partially covered cistern at its base. Rain water is delivered to the cistern free of silt, and the tank cover minimizes evaporation. These are especially suited to areas of summer rainfall.

The spillway is extremely important to the longevity of a dam and frequently is the weak point that causes a dam to give way. A good spillway should be adequate to carry off more than the expected volume of water and should be constructed carefully in order that side cutting cannot occur (Fig. 149). A successful type of construction is that having the outlet at the upper end of the reservoir at a safe level below the top of the dam. A ditch conveys the water around the side of the reservoir and conducts it to the stream channel below the dam; or, better, the ditch may lead the water away from the channel and spread it over adjacent land. An outlet at the upper end of the reservoir has two advantages in that floods are less likely to harm the dam and, after the reservoir is full, silt is not deposited in the reservoir but is carried around the structure, materially lengthening the life and period of usefulness.

Additional precautions against silting are desirable and add to the life of reservoirs. Careful grazing of the drainage above the reservoir is advisable. Construction of a silt trap at the head of the reservoir by fencing an area and allowing rank vegetation to filter the water is recommended.

Often a satisfactory reservoir may be built by excavating to water-bearing strata. These, known as pit reservoirs, fill primarily from underground seepage rather than surface runoff.

Sand Tanks. A special type of structure known in the Southwest as a desert sand tank has certain advantages over the ordinary open reservoir (33). Ordinary reservoirs, in regions of heavy and sudden storms, soon may be filled by silt, and the dam becomes useless. Desert sand tanks turn this fact to an advantage. They are essentially reservoirs, except that they are expected to fill up with detritus, and provision is made for drawing the water from underneath the porous material. This is done by means of a collection box, at the base of the upper side of the dam, constructed of loosely joined rocks allowing water to seep through. A pipe inserted in this collection box and extending through the dam permits water to be drawn off. Such structures, though not useful in areas of heavy soils, where the detritus is impervious, work well in regions of coarse soils. Although they do not have so great a capacity as open reservoirs, the percentage of free space between the soil particles available for storing water may be 25 to 30 per cent of the volume of the structure. Lesser capacity is compensated in part by reduced evaporation.

Pipe Lines. Often laying pipe lines from a source of supply to a part of the range not supplied with water is the most feasible means of developing stock water. This may be less expensive than a new water develop-

ment, but it is possible only where an existing development supplies more water than can be used at that point. If excess water is available, then the cost of developing new water sources in another area, topography, distance, and cost of piping must be considered. The pipe line has an advantage over most types of water development in that the cost of upkeep is not so great; hence the operator may be able to afford greater initial investment.

Hauling Water. Many ranges in the West where water is scarce and development costly are now grazed by livestock that receive all their water from hauling. Although this method of securing water generally is too costly for common use, it is proving effective under special circumstances. Studies conducted on salt-desert winter sheep ranges (15) indicated a cost per head per month for a 10-mile haul to be 7 to 14 cents (1946 prices). Because of better gains and lower cost, daily watering was recommended. Winter bands of 2,800 to 3,000 head require a 1,000-gal. tank plus ten 100-gal. troughs. The troughs are moved to a new location each day, which permits better distribution of animals over the range than would be possible using permanent water developments.

STOCK TRAILS AND ROADS

Much of the mountainous range land of the West is so steep and rocky that animals, especially cattle, do not readily traverse it. Such topography is especially serious where water is found only at the bottom of steep canyons and animals must climb out of the canyon to forage. The construction of trails and bridges in such areas offers an opportunity to increase greatly the use of the range by obtaining more uniform utilization. In addition, a major value of a graded stock trail lies in the protection of watersheds by a lessened use of steep areas close to stock-watering places. The trail should be so located as to reduce, rather than to increase, grazing of slopes so steep that grazing is dangerous to soil conservation (11).

Frequently heavy brush and timber prevent ready movement of livestock between areas suitable for grazing. Trails through such areas permit grazing to the benefit both of the livestock and the range.

The grade of a trail should not exceed 15 per cent except for very short distances. Where the trail crosses steep slopes, treads 24 to 36 inches wide are adequate for cattle, though grading out to 4 ft. or more is desirable. Sheep trails should be much wider.

Drain bars for the purpose of diverting runoff and reducing cost of maintenance are essential to trails on sloping topography. These are placed diagonally across the trail at frequent intervals. A log 8 to 10 inches in diameter makes an ideal bar (11).

From the standpoint of range management, the construction of range access roads has major advantages. Good roads are an encouragement to trucking animals rather than trailing. They also offer a means whereby supplemental feeds may be hauled into distant range areas and stored for use during the winter. This makes it possible to use ranges during the winter which otherwise would be useless because of danger from heavy snows. Good road distribution greatly facilitates transportation of camp equipment and range materials such as salt. In addition, roads are useful in the control of fires.

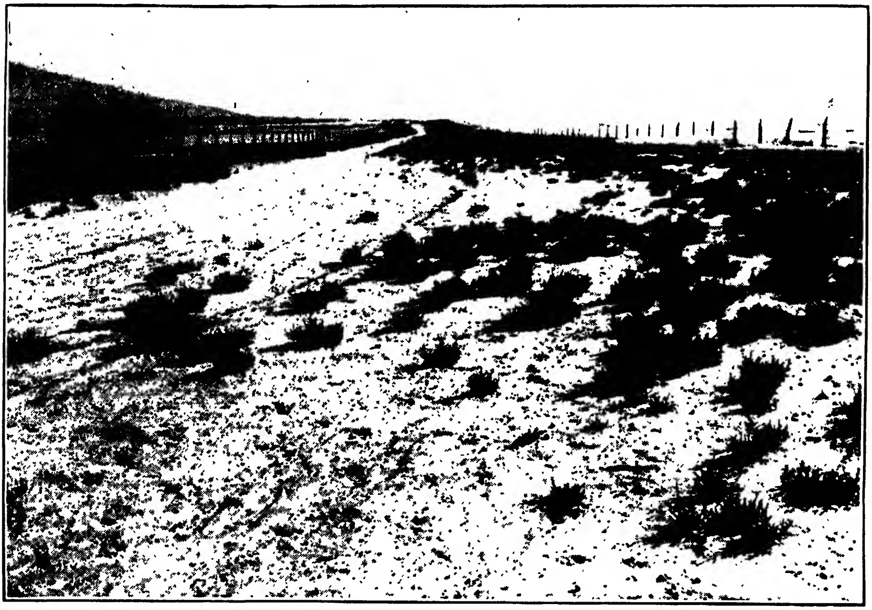

FIG. 150. A fenced stock trail in central Utah. Perennial plants have been killed, leaving only the low-value Russian thistle (*Salsola kali tenuifolia*) within the driveway.

STOCK DRIVEWAYS

Stock movement in the early days was no problem, for land was free and feed abundant. Now cultivation of land and the barbed-wire fence greatly restrict stock movement. These have made stock driveways necessary. Although increased numbers of roads and cheaper transportation facilities have resulted in great numbers of livestock being transported, extensive driveways still remain necessary.

Driveways should be easily accessible and are best located in proximity to highways, so camp outfits and service facilities are available. In the case of ranges distant from roads, open ridges are suitable. The driveway should be wide enough to accommodate the usual-sized herd without

undue crowding and should be fenced where adjacent roads or fields might be injured by straying animals (Fig. 150). Desirable additions to the long driveway are frequent holdover grounds, which are fenced areas for resting or feeding stock en route.

RANGE FENCES

Good fences, properly located and maintained, are of great importance to proper range management. Although under certain conditions range fencing is not necessary, the fence, especially with cattle, facilitates use of the range. In early days of the range industry, the lack of fences was sometimes of advantage to operators, particularly to owners of large herds. Under such conditions, large herds could graze anywhere and their owner could discourage other and smaller operators from using the range. Under present conditions, this has necessarily changed, and desired management can be accomplished only by fencing systematically or by careful herding and supervision.

Fences may entirely enclose a range unit or they may be only drift fences. A *drift fence* is an incomplete one, merely placed across an area where animals customarily pass, to keep stock from drifting from one area to another. On many western ranges, there is marked difference in the time of forage readiness in the spring. Since cattle generally move along the streams and drainages, it is possible to keep the animals from the higher elevations where growth begins late, by placing a drift fence across the drainages. Cattle do not prefer to climb steep slopes; hence, such a drift fence run but a short distance up the sides of the canyon is sufficient to hold a herd on the seasonal range desired. This reduces the amount of fence necessary.

One of the most important functions of a fence is that of securing proper distribution of stock. If fences are strategically located, good distribution can be accomplished at small expense. Fences used for distribution need not be so constructed as completely to prevent animal movement from one area to another, as with boundary fences, for no great harm is done if a few slip by.

Barbed-wire Fences. The most common fencing material used in the West is barbed wire. The advantage of this type is that materials can be transported more readily to the places needed and construction costs are less than for most other types of fence. In the Southwest, a smooth wire occasionally is preferred to barbed wire because of the screwworm infection which may follow cuts from barbed wire (24).

Although many types of fence construction are used, experience has shown that certain specifications should be met if the fence is to be adequate (Fig. 151). In constructing range fence for control of cattle

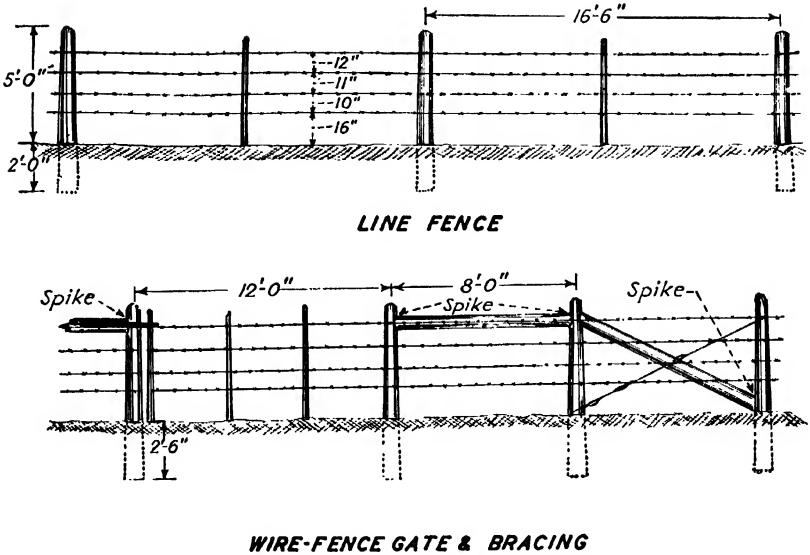

FIG. 151. Barbed-wire-fence construction detail showing gate and bracing structure. [*After U.S. Forest Service* (36).]

and horses, not less than four strands of wire should be used and posts should be not over 16 ft. apart. Stays, jumpers, or dancers are often placed midway between the posts for additional support. The wires should be approximately 1 ft. apart, the bottom one about 15 inches from the ground. This provides a fence slightly over 4 ft. in height. Some state standards for fence construction are shown in Table 69.

TABLE 69. MINIMUM STATE STANDARDS FOR BARBED-WIRE FENCES FOR WESTERN STATES HAVING STATE REGULATIONS
Data from Bureau of Land Management (38)

State	Wire strands					Posts			Stays	
	Number	Heights of strands from the ground, inches				Top diameter, inches	Distance in ground, inches	Maximum spacing, feet	Number	Maximum spacing, feet
		1st	2nd	3d	4th					
Arizona	4	50	38	28	18	..	..	30	3	7½
Colorado	3	46	32	20	..	3	18	33	1	16½
Idaho	3	47	34	21	..	..	..	24	3	6
Montana	3	44	30	15	..	..	..	33	2	11
New Mexico	4	48	36	24	12	2	..	33	3	8
Wyoming	3	48	Optional	Optional	..	4	20	33	2	11

One of the serious difficulties with wire fences in regions of heavy snowfall is that accumulations of snow will break down the fence. As the snow settles and compacts, the wire is held firmly and either is pulled from the posts or is broken. With the coming of spring, considerable repair is necessary. The difficulty can be obviated, however, by building fences of the let-down type. This is done by driving two staples into the post just far enough apart for the wire to go between them. The wire is inserted and a third staple is placed through the two original ones to hold the wire against the post. In the fall, this staple can be removed and the wire laid on the ground. The use of dancers between the posts makes this process more simple, since they prevent the wires from becoming entangled.

Woven-wire Fences. Sheep-tight fence is rare on the range except in parts of Texas. The cost of fence plus the need for protection from predatory animals generally has resulted in the use of herding rather than fencing for the control of sheep. Barbed wire is seldom used for sheep, since wires must be not over 6 or 8 inches apart and must be very close to the ground. Woven wire 30 to 36 inches high, with two strands of barbed wire above, makes a satisfactory sheep fence. Woven wire should always be topped by a strand of barbed wire. This protects the woven wire from being ridden down, since the single wire can be more tightly stretched, and the barbs discourage animals from rubbing against it. To enclose relatively small areas such as buck pastures, cultivated fields, or feed-storage areas, woven-wire fencing has proved to be highly satisfactory.

Pole Fences. Poles rather than wire are used for fence construction in many parts of the West. In wooded areas, materials can be secured readily without undue expenditure. Poles withstand heavy snows common in many regions, and in rough rocky areas they make digging holes for posts unnecessary. They are expensive, however, in respect to the labor that is required in their construction.

There are several types of pole fence used, the log and block, the worm, and the buck pole being common (Figs. 152, 153, and 154).

Electric Fences. A type of fence popular for some uses in the West is the electric fence. Since the construction need not be solid enough to resist animals and generally only one wire is needed, the posts need not be firmly placed or closely spaced; hence there is a distinct saving in both labor and materials. The fence can be constructed for 20 per cent or less of the cost of barbed-wire fence. The posts may be either metal or wood and may be driven into the ground. The wire should be attached to the posts by means of suitable insulators.

The source of the current may be a battery or a standard power plant, provided that a transformer attachment is used. The battery is safer

and will last a long time, for the current is not continuous, flowing only upon contact with the animal. An ordinary 6-volt dry-cell battery can be used.

Electric fences function well when the animals have been educated to them. Generally, they are less successful in handling sheep, though they manage hogs, cattle, and horses effectively. Even intractable bulls

FIG. 152. A log- and block-type pole fence made of aspen logs.

are subdued by them. As drift fences, they are being used on the open range and are distinctly advantageous where low-cost fences, especially of a seasonal nature, must be built. Their use in controlling big-game animals is not satisfactory; these animals pay little attention to them and do not investigate them before crossing, a necessity if they are to be effective (8).

Some difficulty has been experienced when the electric fence is used in very dry areas because dry soil makes a poor ground connection and a weakened shock results. Under such conditions a second wire, which is

grounded to complete the circuit, may be needed. Once domestic animals have become acquainted with the fence they do not go near it, and dry-soil periods cause little trouble (21).

Vegetation coming into contact with the electric fence inactivates it. For this reason cutting or spraying vegetation near the wire may be necessary and electric fencing may prove impractical in brushy country.

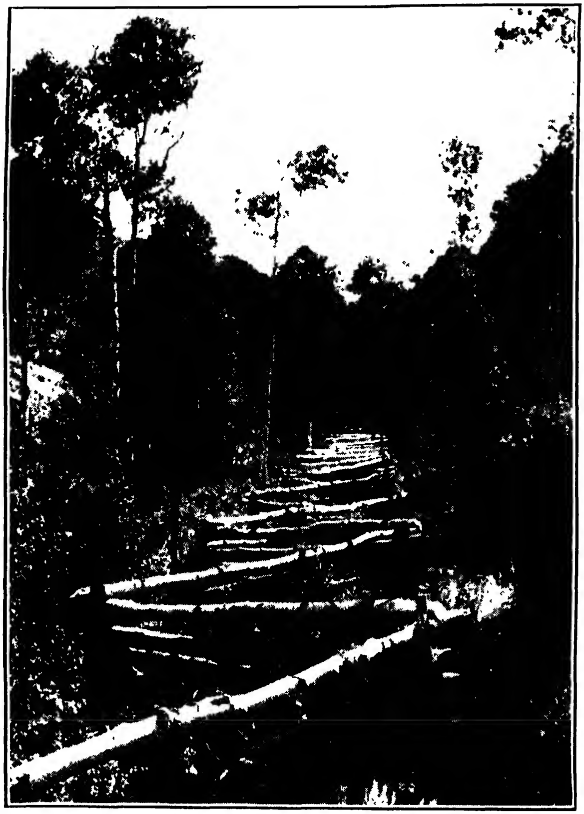

FIG. 153. Worm fence of aspen poles. After 6 years of use this fence had settled enough to necessitate a new pole being added above.

Fence Posts. The most common post in the West for both barbed-wire and woven-wire fence is the unpeeled native juniper, locally known as cedar. This is the most durable of the native post materials. Treatment is seldom practiced because in dry soils untreated posts frequently have a life span of over 20 years. If the diameter of the heartwood is not less than 4 inches, a life span of 40 years is common.

Aspen, lodgepole, and oak posts also are widely used but these do not last long unless treated. Seasoned posts should be soaked 12 to 24 hours in a 5 per cent solution of pentachlorophenol in fuel oil. Zinc salts in water

solution can be used to treat green posts, a distinct advantage to the rancher.

For best results, posts should be set firmly to a depth of 2 ft. and at least 5 ft. should remain aboveground. Corner posts should be especially large and deeply set and should be carefully braced (Fig. 151). Additional bracing and care are necessary for posts near corners and at the tops of ridges and bottoms of hollows in rough country, since a strain is exerted on the fence at these places.

FIG. 154. A buck-pole fence constructed of lodgepole pine.

IMPROVEMENTS TO CONSERVE WATER

On abused range land and even on normal ranges, surface runoff from storms may represent a large proportion of the precipitation. The Great Plains and the Southwest are particularly subject to high surface runoff from summer rains. This accentuates the natural aridity and results in lessened forage production. Minimizing these water losses is important to a well-developed and well-managed range. Range improvements to conserve water also function to increase forage yield and to hold soil in place. In fact, erosion control may be the primary objective. Several devices have been used to achieve this end such as terracing, contour furrowing, water spreading, chiseling, and pitting.

Terraces. Where precipitation is low, the aim of a terrace is to retain water on the land and allow it to percolate into the soil where it can be used by vegetation. This necessitates a level terrace or one having a very

slight gradient conducting the water away from the natural drainage. On ranges, expensive terracing is resorted to only when the terrace cost is exceeded by the property damage being done on lower-lying lands by the runoff or when a jeopardized city-water supply or irrigation system demands immediate attention. Occasionally, however, an inexpensive terrace is advisable, often alternating with a number of furrows (Fig. 155).

The size or capacity of the terrace varies with the topography and the amount and distribution of precipitation to which past weather records

FIG. 155. A system of one pasture ridge followed by a series of five pasture furrows 2 years after construction in Colorado. Furrows can be seen to the left of the ridge in the foreground. The large ridges have been particularly effective in holding drifting snow. The vegetation, chiefly blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchlöe dactyloides*), recovered rapidly after this treatment. (*Courtesy of U.S. Soil Conservation Service.*)

show the area to be subjected. A coefficient of runoff must be computed for each slope, and the needed terrace capacity calculated. It is well to allow a margin of safety of 10 to 25 per cent. The coefficient will vary considerably depending primarily upon soil, vegetation, and topography.

Italian workers, who originated the terracing of nontillable lands, recommend that terraces be about 20 ft. apart and have an average width of 2 to 4 ft. (28). Forest Service work indicates that terraces should have a cross partition or baffle every 20 to 40 ft., the terrace being thus divided into a number of independent sections (Fig. 156). The advantage is that,

if a break occurs in the terrace, only a small part will be drained and flood damage will be at a minimum (2).

Contour Furrows. Because of the high cost of terracing, increasing interest has developed in the use of contour furrows for range land. They serve an important role in that they are inexpensive yet effective in

FIG. 156. A type of terrace developed by the U.S. Forest Service on the very steep Davis County watersheds in Utah showing baffles to prevent drainage in case of a break in the terrace. Such terraces later are seeded to grasses, which ultimately control the erosion, as the terraces are not maintained.

increasing production on low-value ranges. The furrow differs from the terrace in being smaller and in depending primarily upon the soil excavation rather than the ridge for water retention.

Contour furrows are plowed or listed strips placed close together and generally not smoothed after plowing. The contour furrow may be continuous, or it may be a series of staggered strips. The plow is jumped

out of the ground at distances of 15 to 50 ft. to leave blocks 3 to 6 ft. long; drainage is thus stopped in cases where the furrow is not exactly on the contour. It has been observed that rainfall may percolate into the ground 6 to 18 inches deeper on land so furrowed (29). Furrowing can be done with machinery to be found on any ranch.

The Soil Conservation Service has found that for most range contouring best results are obtained from furrows 5 inches deep and 42 to 84 inches apart, though a spacing of 25 to 50 ft. is common on more arid ranges. Furrows 8 to 12 inches wide and 4 to 7 inches deep regrass in 1 to 3 years in the southern plains (20).

Tests on ranges in Texas (19) in which the land was listed to a depth of 3 inches showed grass yield to increase as much as 3.9 times as a result of increased soil moisture and depth of penetration. Native grass increased in both ground cover and production, and forbs decreased. The equivalent of 1.19 inches of moisture was available in the surface 6 ft. of soil on unlisted ranges, 69 per cent of which was in the upper 2 ft. Listed areas contained 2.63 inches and 50 per cent was in the upper 2 ft. An increase of 79 per cent in the weight of root material was obtained (7).

Contour furrows and ridges usually are not desirable on the southern Great Plains on loose, sandy soils, on rough broken lands, or on steep slopes. They are impractical when large quantities of sand and silt accumulate in them. On steep slopes, contour structures do not resod rapidly and seem to encourage low-value weeds. Sandy areas absorb water rapidly and do not require contour furrows (20).

Water Spreading. Terraces and furrows, although effective in erosion control, may have limited effect in increasing vegetation because of the small area affected by them. For this reason much attention has been given to the construction of dikes for water spreading to increase the area of absorption. Water spreading must be limited to relatively level lands, usually 1 to 5 per cent slopes. The advantage of spreader systems over terraces and furrows is that water is dissipated over large areas rather than being collected in narrow terraces or ditches. This results in a greater percentage of the area receiving floodwaters.

Although details vary enormously, the principle involved is to remove water from natural drainage ways and conduct it by means of dikes back and forth across neighboring slopes where it gradually filters into the soil. The aim should be to bring the maximum area under the influence of the dikes by so spacing and locating them that flooding will occur over virtually the entire area. Pipes may be inserted through the dikes or parts may be composed of brush to permit part of the water to escape, effecting a gradual liberation and greater spread of the water.

Spreading water has so greatly increased grass growth on range areas in New Mexico that hay can be harvested from lands formerly of low

production even for grazing. Similarly, forage increases of 350 per cent have been noted on areas in Montana as a result of spreader construction (37). Spreaders are perhaps fully effective only on heavy soils; results in the Southwest on light soils showed no increased forage production (39).

Pitting and Chiseling. Less elaborate treatments to facilitate water penetration and increase herbage yields are pitting or chipping and chiseling. The former has had some success in the Southwest and in the short-grass plains where the soil surface may become quite impervious, the small basins formed by off-center or irregularly shaped disks holding water until it penetrates the ground (Fig. 131, page 371). Increases in grazing capacity of 33 per cent have been noted on short-grass plains from pitting (4, 5).

Chiseling is used on heavy gumbo soils and where hardpans form beneath the soil surface. Not only is water penetration slow on these areas, but plants find it difficult to establish themselves in the compacted soils. Road rippers or special machines with strong teeth designed to break through the compacted layers are used in order to permit infiltration. Experience indicates that chiseling is ineffective unless the soil surface receives considerable disturbance (4).

It would appear that wherever water is lost by surface runoff some mechanical treatment of the soil may increase forage production. The increase secured will depend upon the percentage of the soil surface affected by the treatment. Water collected in deep terraces spreads little laterally; hence large structures, widely spaced, will increase forage but slightly. Small closely spaced furrows, spreader dikes, or pits, which leave no appreciable area untreated are usually preferable.

RANGE FERTILIZATION

Fertilization of croplands has long been practiced, and pastures generally show markedly increased yields from fertilizers. The advantages suggested for pasture fertilization have been increased yields, higher nutritive value of the forage, and earlier growth in the spring. Some interest has been directed toward discovering whether or not similar results might be secured on dry range lands.

Fertilizer treatments on California annual-plant ranges have shown remarkable increases in herbage production resulting from the addition of nitrogenous fertilizers (6, 13). Phosphate and lime did not significantly affect production; however, marked increases, especially of the legumes, occur in some areas in California from the application of gypsum (9).

The application of phosphates to range lands in the Gulf Coast region almost doubled herbage production and increased phosphorus content of the herbage as much as 300 per cent. As a result, cattle grazing on the

range secured ample phosphorus from the forage alone, except when drought severely curtailed herbage production. It was concluded that fertilization was the most effective means of supplying supplemental phosphorus to the animal during periods of normal precipitation (27).

Nitrogen, phosphorus, and potassium fertilizers and certain trace elements were applied to ranges of several different soil types in Colorado. The soils were of various origins including granite, andesite, basalt, and shale parent materials. Nitrogen produced increased herbage yields, and potassium showed some response on granite soils. No other treatments or soils showed benefits (26).

It appears that the use of fertilizers on range land should be limited to areas of high moisture such as meadows or areas where rainfall is high during the growing season. Experience on cultivated lands as well as limited experience on ranges suggests that the response secured is related to climate, to the soil material, and to the type of vegetation. Much experimentation will be necessary before effective and general use can be made of range fertilization. Doubtless many areas can be made to yield greater forage crops when factual data become available, but there is distinct danger of actual reduction in yield accompanying fertilization on arid lands, especially during drought years, because rapid growth during favorable growing periods produces herbage having a transpiration requirement greater than the soil can supply.

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